U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-274 553

# Investigation of Diesel-Powered Vehicle Emissions. Part VII

Southwest Research Inst, San Antonio, Tex

Prepared for

Environmental Protection Agency, Ann Arbor, Mich Emission Control Technology Div

Feb 77

PB 274 553

EPA-460/3-76-034

February 1977

# INVESTIGATION OF DIESEL-POWERED VEHICLE EMISSIONS VII

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

## TECHNICAL REPORT DATA

*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO.<br>EPA-460/3-76-034 | 2. | 3. RECIPIENT'S ACCESSION NO.<br>PB274553 |
| 4. TITLE AND SUBTITLE<br>Investigation of Diesel Powered Vehicle Emissions Part VII | | 5. REPORT DATE<br>February 1977 |
| | | 6. PERFORMING ORGANIZATION CODE<br>11-4016 |
| 7. AUTHOR(S)<br>Karl J. Springer | | 8. PERFORMING ORGANIZATION REPORT NO.<br>AR-1166 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Southwest Research Institute<br>P.O. Drawer 28510<br>8500 Culebra Rd.<br>San Antonio, Texas | | 10. PROGRAM ELEMENT NO. |
| | | 11. CONTRACT/GRANT NO.<br>68-03-2116 |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>U.S. Environmental Protection Agency<br>OMSAPC - ECTD<br>Ann Arbor, Michigan 48105 | | 13. TYPE OF REPORT AND PERIOD COVERED<br>Final Report-Part VII 6/74-11/76 |
| | | 14. SPONSORING AGENCY CODE<br>[illegible] |

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Five light duty diesel vehicles and five heavy duty diesel engines were tested over various test cycles for both regulated and unregulated emissions. A Mercedes 220 D, Mercedes 240 D, Mercedes 300 D, Peugeot 2040, and an International Harvester pick-up truck with a Perkins 6-247 engine were the light duty diesel vehicles tested. The heavy duty diesels included a Detroit Diesel 6V-71 city bus engine with two injector designs, a Cummins NTC-290 truck engine operated with and without variable timing, and a Detroit Diesel 8V-71TA truck engine. Emissions measured included HC, CO, $NO_x$, $CO_2$, smoke, adlehydes, exhaust odor, benzo (a) pyrene, sulfate, sulfur dioxide, and particulate mass.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Exhaust Emissions<br>Diesel Engines<br>Odor/Smoke<br>Particulate<br>Nitrogen Oxides<br>Carbon Monoxide<br>Hydrocarbons | Heavy Duty Vehicles<br>Heavy Duty Engines<br>Light Duty Vehicles<br>Emission Test Procedures | |

| | | |
|---|---|---|
| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES<br>407 |
| | 20. SECURITY CLASS *(This page)* | 22. PRICE<br>PCA18-A01 |

EPA Form 2220-1 (9-73)

EPA-460/3-76-034

# INVESTIGATION OF DIESEL-POWERED VEHICLE EMISSIONS VII

by

Karl J. Springer

Southwest Research Institute
P.O. Darwer 28510
8500 Culebra Road
San Antonio, Texas

Contract No. 68-03-2116

EPA Project Officer: R.C. Stahman

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

February 1977

1a

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - in limited quantities - from the Library Services Office (MD-35), Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas, in fulfillment of Contract No. 68-03-2116. The contents of this report are reproduced herein as received from Southwest Research Institute. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-460/3-76-034

# ABSTRACT

Evaluation of regulated and a variety of non-regulated emissions from four diesel powered cars, one diesel powered pick-up truck and five diesel engine configurations used in trucks and buses are reported. The cars were a comprex equipped Mercedes 220D, Mercedes 240D and 300D, Peugeot 204D and the pick-up was powered by a Perkins 6-247 diesel engine. A bus engine, Detroit Diesel 6V-71 (run with two injector designs) and two truck engines, a Cummins NTC-290 (run in two timing configurations) and a Detroit Diesel 8V-71TA, comprised the heavy duty engines evaluated. A DF-2 diesel fuel, similar to a national average fuel, was used in all evaluations except the bus engine, which was operated on a kerosene DF-1 fuel.

Measurements included unburned hydrocarbons, carbon monoxide, oxides of nitrogen and smoke. A variety of non-regulated emissions including aldehydes, odor, particulate, selected hydrocarbon components, sulfate, sulfur dioxide, polynuclear organic matter, carbon hydrogen nitrogen and sulfur content of the particulate, fuel consumption/economy and noise and performance (cars and pick-up only). The basic test procedure included several recognized transient driving cycles for the cars and the 13-mode Federal Test Procedure for the dynamometer operated heavy duty diesel engines. Emission rates are computed and summarized for both light duty and heavy duty diesels. Expression in terms of mass per unit of time, per unit of fuel consumed, and per unit of distance driven (light duty) or per unit of power output (heavy duty) allow direct comparison between different cars or different engines as well as with previously reported data.

# FOREWORD

This project was conducted for the U. S. Environmental Protection Agency by the Department of Emissions Research, Automotive Research Division of Southwest Research Institute. The EPA Project Officer was Mr. Ralph C. Stahman. Assisting the Project Officer on this project and hereby acknowledging their assistance were Mr. John J. McFadden and Dr. Joseph Somers, both of the Ann Arbor, Michigan EPA laboratories.

The project was under the overall direction of Mr. Karl J. Springer, Director of the Department of Emissions Research, who served as Project Manager. Mr. Harry E. Dietzmann was responsible for the chemical and analytical studies. Mr. Daniel A. Montalvo performed the odor studies with the prototype CRC CAPE-7 DOAS method.

The project began in June 1974 and was authorized under Contract 68-03-2116. It was known within Southwest Research Institute as Project 11-4016-001 and constituted Part VII of a long range investigation of diesel emissions begun in 1966.

## TABLE OF CONTENTS

Page

ABSTRACT iii

FOREWORD iv

LIST OF FIGURES vii

LIST OF TABLES xi

I. SUMMARY 1

II. INTRODUCTION 7

A. Background 7
B. Objective 8
C. Coordination Conference 8
D. Acknowledgement 8

III. DESCRIPTION OF ENGINES, VEHICLES, FUELS AND PROCEDURES 10

A. Heavy Duty Engines 10
B. Diesel Powered Light Duty Vehicles 10
C. Test Fuels 10
D. Test Plan 15
E. Procedures and Analysis 16

IV. RESULTS OF FIVE HD DIESEL ENGINES 52

A. 13-Mode Gaseous Emission Results 52
B. Federal Smoke Results 56
C. Odor and Related Instrumental Analyses 60
D. Particulate, Sulfate and $SO_2$ Results 79
E. Polynuclear Aromatic Hydrocarbons 104
F. Discussion and Summary 115

V. RESULTS OF FIVE DIESEL POWERED LIGHT DUTY VEHICLES 124

A. Regulated Emissions and Fuel Economy 124
B. Smoke 127
C. Particulate, Sulfate, $SO_2$ and PNA Results 139
D. Odor and Related Instrumental Analyses 150
E. Vehicle Noise and Performance 173

## TABLE OF CONTENTS (cont'd)

Page

LIST OF REFERENCES 178

APPENDIXES

A. Selected Tables and Figures from Petroleum Products Survey No. 82
B. Chemical - Analytical Procedures
C. Computer Reduced 13-mode Federal Test Results for Five Heavy Duty Engines
D. Results of Federal Smoke Test of Five Heavy Duty Engines
E. Odor Rating by EPA Q/I Method of Five Heavy Duty Engines
F. Instrumental-Wet Chemical Exhaust Data Taken during Odor Test of Five Heavy Duty Engines
G. Computer Reduced 1975 FTP, SET and FET Gaseous and Fuel Economy Data for Five LD Diesel Vehicles
H. Particulate Emission Rates for Five LD Diesel Vehicles
I. Sulfate and $SO_2$ Emission Rates for Five LD Diesel Vehicles
J. Odor Ratings by Trained Panel for Five LD Diesel Vehicles
K. Instrumental - Wet Chemical Exhaust Data Taken During Odor Test of Five LD Diesel Vehicles
L. Noise Data for Five LD Diesel Vehicles

## LIST OF FIGURES

| Figure | | Page |
|---|---|---|
| 1 | HD Diesel Engines under 13-mode Gaseous Emissions Federal Test Procedure | 18 |
| 2 | Schematic of One Cycle of Federal Smoke Compliance Test | 20 |
| 3 | Gaseous and Smoke Emissions Measurement from LDV's During Transient Cycles | 22 |
| 4 | Odor Measurement by Trained SwRI Panel | 25 |
| 5 | Gaseous Emission, DOAS and DNPH Sample Trapping During Odor Evaluation | 30 |
| 6 | Schematic Section of Dilution Tunnel for Diesel Particulate Sampling | 36 |
| 7 | LDV Particulate Emission Measurement | 38 |
| 8 | HD Engine Particulate Emission Measurement | 40 |
| 9 | Measurement of Sound Level From Light Duty Diesel Powered Vehicles | 50 |
| 10 | Detroit Diesel 6V-71 Engine Diesel Odor Intensity by Trained Panel | 70 |
| 11 | Cummins NTC-290 Engine Diesel Odor Intensity by Trained Panel | 71 |
| 12 | Detroit Diesel 8V-71 Engine Diesel Odor Intensity by Trained Panel | 72 |
| 13 | Detroit Diesel 6V-71 Engine Diesel Odor Intensity (TIA) by DOAS Method | 73 |
| 14 | Cummins NTC-290 Engine Diesel Odor Intensity (TIA) by DOAS Method | 74 |
| 15 | TIA by DOAS Versus "D" Diesel Odor Rating by Trained Panel for Five HD Diesel Engine Configurations | 76 |

LIST OF FIGURES (cont'd)

| Figure | | Page |
|---|---|---|
| 16 | Particulate Emission Rates from Detroit Diesel 6V-71 Bus Engine Based on 47mm Glass Filter | 88 |
| 17 | Sulfate ($SO_4^=$) Emission Rates from Detroit Diesel 6V-71 Bus Engine Based on 47mm Fluoropore Filter | 89 |
| 18 | $SO_2$ Emission Rates from Detroit Diesel 6V-71 Bus Engine | 90 |
| 19 | Power Output Fuel and Air Rates from Detroit Diesel 6V-71 Bus Engine During 7-Mode Tests | 91 |
| 20 | Particulate Emission Rates from Cummins NTC-290 Truck Engine based on 47mm Glass Filter | 92 |
| 21 | Sulfate ($SO_4^=$) Emission Rates from Cummins NTC-290 Truck Engine Based on 47mm Fluoropore Filter | 93 |
| 22 | $SO_2$ Emission Rates from Cummins NTC-290 Truck Engine | 94 |
| 23 | Power Output Fuel and Air Rates from Cummins NTC-290 Truck Engine During 7-Mode Tests | 96 |
| 24 | Particulate Emission Rates from Detroit Diesel 8V-71TA Truck Engine Based on 47mm Glass Filter | 97 |
| 25 | Sulfate ($SO_4^=$) Emission Rates from Detroit Diesel DDAD 8V-71TA Truck Engine Based on 47mm Fluoropore Filter | 98 |
| 26 | $SO_2$ Emission Rates from Detroit Diesel DDAD 8V-71TA Truck Engine | 99 |
| 27 | Power Output Fuel and Air Rates from Detroit Diesel DDAD 8V-71TA Truck Engine During 7-Mode Tests | 100 |
| 28 | Sulfate as Percent of S in Fuel for various HD Engine Configurations | 103 |

LIST OF FIGURES (cont'd)

Figure Page

29 B:ESO Emission Rates from Detroit Diesel 6V-71 Bus Engine Based on 8 x 10 Glass Filter 108

30 B:ESO Emission Rates from Cummins NTC-290 Truck Engine Based on 8 x 10 Glass Filter 109

31 B:ESO and BaP Emissions Rates from Detroit Diesel 8V-71TA Truck Engine Based on 8 x 10 Glass Filters 110

32 Comparison of Particulate g/hr Rates by 8 x 10 and 47mm Glass Filters for Detroit Diesel 6V-71 Engine 112

33 Comparison of Particulate g/hr Rates by 8 x 10 and 47mm Glass Filters for Cummins NTC-290 Engine 113

34 Comparison of Particulate g/hr Rates by 8 x 10 and 47mm Glass Filters for Detroit Diesel 8V-71 TA 114

35 Brake Specific B:ESO, BaP and Particulate from Five Heavy Duty Diesel Engine Configurations 119

36 Brake Specific $SO_2$ and $SO_4^=$ Emissions from Five Heavy Duty Diesel Engine Configurations 120

37 Brake Specific CO and NO as $NO_2$ Emissions from Five Heavy Duty Diesel Engine Configurations 122

38 Brake Specific HC and HC+$NO_2$ Emissions from Five Heavy Duty Diesel Engine Configurations 123

39 Typical Mercedes 220D Comprex "Cold Start" Smoke Trace 131

40 Typical Mercedes 240D "Cold Start" Smoke Trace 132

41 Typical Mercedes 300D "Cold Start" Smoke Trace 133

42 Typical Peugeot 204D "Cold Start" Smoke Trace 134

43 Typical Perkins 6-247 "Cold Start" Smoke Trace 135

# LIST OF FIGURES (cont'd)

| Figure | | Page |
|---|---|---|
| 44 | Particulate Emission Rates of Five Diesel LD Vehicles | 142 |
| 45 | Sulfate Emission Rates of Five Diesel LD Vehicles | 147 |
| 46 | B:ESO Emission Rates of Five Diesel LD Vehicles | 151 |
| 47 | Average Odor Ratings for Mercedes 220D Comprex Diesel Light Duty Vehicle at 100:1 Dilution | 154 |
| 48 | Average Odor Ratings for Mercedes 240D Diesel Light Duty Vehicle at 100:1 Dilution | 155 |
| 49 | Average Odor Ratings for Mercedes 300D Diesel Light Duty Vehicle at 100:1 Dilution | 156 |
| 50 | Average Odor Ratings for Peugeot 204D Diesel Light Duty Vehicle at 100:1 Dilution | 157 |
| 51 | Average Odor Ratings for Perkins 6-247 Diesel Light Duty Vehicle at 100:1 Dilution | 158 |
| 52 | TIA by DOAS Versus "D" Odor Rating by Trained Panel for Five LD Diesel Vehicles | 163 |
| 53 | Summary of FTP, SET-7 and FET Results | 165 |

# LIST OF TABLES

| Table | | Page |
|---|---|---|
| 1 | Description of HD Diesel Engines | 11 |
| 2 | Description of Diesel Powered LD Test Vehicles | 12 |
| 3 | Summary of 1973 Bureau of Mines Diesel Fuel Survey of City Bus and Truck-Tractor Fuel Properties | 14 |
| 4 | Odor Test Conditions - HD Engines | 27 |
| 5 | Odor Test Conditions - LD Vehicles | 28 |
| 6 | 13-Mode FTP Gaseous Emissions Results for Five HD Diesel Engine Configurations | 53 |
| 7 | Heavy Duty Diesel (And Gasoline) Emission Limits | 54 |
| 8 | Federal Smoke Test Results for Five HD Diesel Engine Configurations | 57 |
| 9 | Smoke Test Results During Maximum Power Test for Five HD Diesel Engine Configurations | 58 |
| 10 | Average Odor Panel Ratings of HD Diesel Engines | 61 |
| 11 | Average of Exhaust Analyses Taken Simultaneously with odor ratings of HD Engines During Steady-State Conditions | 63 |
| 12 | Average Engine Operating Data Taken Simultaneously with Odor Ratings of HD Engines During Steady-State Conditions | 66 |
| 13 | Distribution of Exhaust Hydrocarbon Emissions During Steady-State Odor Tests, ppm C | 77 |
| 14 | Aldehydes by DNPH for DDAD 8V-71TA Engine | 80 |
| 15 | Summary of Particulate, Sulfate and $SO_2$ from 47mm Glass and Fluoropore Filter Samples | 81 |
| 16 | Summary of Engine Operating Conditions 47mm Glass and Fluoropore Filter Tests | 86 |

## LIST OF TABLES (cont'd)

| Table | | Page |
|---|---|---|
| 17 | Elemental Analyses of Filter Collected Samples for Five HD Diesel Engines | 101 |
| 18 | Summary of Particulate, BaP and Organic Solubles from 8 x 10 Size Glass Filter Samples | 105 |
| 19 | 7-Mode Brake and Fuel Specific Calculations - DDAD 8V-71TA | 111 |
| 20 | Summary of Engine Operating Conditions during 8 x 10 Size Glass Filter Tests | 116 |
| 21 | Brake and Fuel Specific Emission Rates of Five Heavy Duty Diesel Engine Configurations | 118 |
| 22 | Federal Light Duty Emission Standards | 124 |
| 23 | HC, CO, $NO_x$ and Fuel Results Five Diesel LDV's (Average of Replicate Runs) | 125 |
| 24 | Comparison of SwRI to EPA Average Transient Results | 128 |
| 25 | Smoke Opacity Values from Smoke Trace, 1975 FTP, LA-4 Cold-Hot Start | 129 |
| 26 | Smoke Opacity Values from Smoke Trace of SET-7 Driving Cycle | 137 |
| 27 | Smoke Opacity Values from Smoke Trace of FET Driving Cycle | 138 |
| 28 | Exhaust Smoke Opacity Readings | 138 |
| 29 | Particulate Emission Rates Five Diesel LDV's (Average of Replicate Runs with 47mm Filters) | 141 |
| 30 | Elemental Analysis of Fiberglass Filter Dilution Tunnel Collected Particulate, % by Weight | 144 |
| 31 | Sulfate and $SO_2$ Emission Results Five Diesel LDV's (Average of Replicate Runs) | 146 |

## LIST OF TABLES (cont'd)

| Table | | Page |
|---|---|---|
| 32 | B:ESO and Particulate Emissions Rates Five Diesel LDV's (Average of Replicate Runs with 8 x 10 Glass Filters) | 149 |
| 33 | Listing of Average Odor Panel Ratings at 100:1 Dilution | 153 |
| 34 | Rough Comparison of LD Vehicle "D" Odor Ratings | 159 |
| 35 | Exhaust Analyses Taken Simultaneously with Odor Ratings During Steady State Conditions | 160 |
| 36 | Comparison of TIA and "D" Odor Values | 161 |
| 37 | DOAS Results During Various Transient Cycles (Five Diesel Powered LDV's) | 164 |
| 38 | Detailed Hydrocarbon Analysis of Samples Taken During Steady-State Odor Tests | 168 |
| 39 | Detailed Hydrocarbon Analysis of Samples Taken During Various Transient Cycles | 169 |
| 40 | Aldehydes from Five LD Diesel Vehicles Obtained During Steady-State Odor Tests | 171 |
| 41 | Aldehydes From Five LD Diesel Vehicles Operated Over Various Transient Driving Cycles | 172 |
| 42 | Summary of Sound Level Measurements for Five Diesel Powered Light Duty Vehicles - dBA Scale | 174 |
| 43 | Acceleration Times for Five Diesel Powered LDV's | 176 |

# I. SUMMARY

Dieselization of passenger cars and light and medium duty trucks is considered as a partial solution to both energy and environmental problems. This report comprises the evaluation of five diesel powered light duty vehicles (LDV) and five diesel engine configurations used in truck and bus heavy duty vehicle (HDV) applications. The LDV's include Comprex equipped Mercedes 220D, Mercedes 240D, Mercedes 300D, Peugeot 204D and an International pick-up truck powered by a Perkins 6-247 engine. The LDV's were operated over three transient driving cycles used in the 1975 Federal Emissions Test (city driving), proposed sulfate emissions cycle (congested freeway driving) and the Federal fuel economy cycle (highway driving).

The five heavy duty engine configurations included a Detroit Diesel Allison Division (DDAD) 6V-71 city bus engine operated with two injector designs, a Cummins NTC-290 truck engine operated with and without variable injection timing and a Detroit Diesel 8V-71TA truck engine. All vehicles and engines were operated on a "national average" type DF-2 fuel except for the 6V-71 which operated on a kerosene type DF-1 fuel consistent with city bus practice. The 13-mode Federal Test Procedure (FTP) used for gaseous emissions of unburned hydrocarbons (HC), carbon monoxide (CO), and nitric oxide (NO) was used as the basic engine test cycle. A 7-mode version of this test was also utilized.

In addition to measurement of the currently regulated emissions from diesel LDV's (HC, CO and oxides of nitrogen, $NO_x$) and from HD diesel engines (HC, CO, NO as $NO_2$ and visible smoke), a wide variety of non-regulated contaminants were determined. These included aldehydes by the dinitrophenylhydrozine (DNPH) method, odor by Public Health Service Quality/Intensity (PHS Q/I) method and the diesel odor analytical system (DOAS), particulate, sulfate, sulfur dioxide ($SO_2$) by the barium chloranilate (BCA) method, benz alpha pyrene (BaP), detailed hydrocarbons, noise (LDV's only), smoke, elemental analysis of particulate and fuel consumption/economy.

Emission rates were computed for the LDV's in terms of mass per unit of time, per unit of fuel consumed and per unit of distance driven for the five LDV's. The results of the five diesel engines were expressed in the same mass rates except mass per unit of power output was used instead of mass per unit distance driven. The data allows direct comparison between each of the five LDV's for each type of driving cycle employed. Similarly, the modal and cycle composite results of the five HD engines can be directly compared to each other.

The key findings are summarized as follows, first for the five HD engine configurations and then for the five diesel powered LDV's.

Heavy Duty Diesel Engines

The turbocharged and aftercooled DDAD 8V-71TA engine was included for baseline purposes in this project. Most of the comments that follow are specific to the two emission configurations of the DDAD 6V-71 and Cummins NTC-290 engines.

Gaseous - Substantially lower NO (as $NO_2$), HC and CO were found for the DDAD 6V-71 when equipped with the constant end of injection B60E injectors set at retarded timing relative to the variable end of injection LSN-60 injectors. The brake specific fuel consumption, mass of fuel burned per unit of work output, increased slightly due to a reduction in maximum power with the retarded timing.

Substantially lower NO (as $NO_2$) but higher HC and CO resulted with the automatic variable injection timing version of the Cummins NTC 290 engine. Brake specific fuel consumption was, like the 6V-71, increased slightly again, presumably due to the lower maximum power observed.

Smoke - Higher Federal smoke test opacities were observed with the B60E, retarded timing configuration of the DDAD 6V-71 bus engine. The "a" accel and "b" lug smoke values were more than doubled from their relatively low 5.5 and 1.9 percent opacity with LSN-60 injectors. The increase in smoke from the city bus engine is a distinct disadvantage for the B60E retarded timing configuration because of the proximity of city buses to the large sectors of the population. No change in smoke output was noted with the "low" emissions configuration of the Cummins NTC-290 relative to its "current" configuration.

Odor - Odor tests by the trained panel revealed that the transient operating conditions continue to dominate the production of odor, being more intense than steady state operation. No significant or consistent differences in perceived odor were found with either emissions configuration of the 6V-71 or NTC-290 engines. Odor intensities ranged from "D" - 2.5 to "D" - 3 for the 8V-71TA, a moderate odor strength.

The diesel odor analytical system (DOAS), developed under Coordinating Research Council direction, resulted in total intensity of aroma (TIA) values that did not correlate with the "D" odor intensity panel ratings for the five HD engine configurations as a group.

Aldehydes - The difficulty in converting from previous methods for formaldehyde, acrolein and aliphatic aldehydes to the DNPH procedure allowed only the last HD engine tested, the DDAD 8V-71TA, to be evaluated. For the first time in this long range project, data are available on formaldehyde, acetaldehyde, acetone, isobutanal, crotanal, hexanal, and benzaldehyde by an improved method.

Particulate - Particulate emission rates for the DDAD 6V-71 were about the same regardless of the injector-timing configuration. The variable timing equipped Cummins NTC-290 emitted about the same rate of particulate as the standard system. The important finding was the substantial range in particulate rate from the two-stroke cycle bus engine and the four-stroke cycle truck engine, on the order of 0.4 to 1.9 g/kW-hr based on a 7-mode cycle. The higher rate of particulate from the DDAD 6V-71 was substantially different in composition having much more hydrocarbon content as unburned or partially burned fuel and lube oil. The NTC-290 particulate was basically soot or carbon.

Sulfate and $SO_2$ - Of the many ways to express the content of sulfate and $SO_2$ in the exhaust, percent sulfur in the fuel converted to either sulfate or $SO_2$ is most instructive. This is especially true where fuel sulfur content varies appreciably as with diesel fuel. On the average, about 2.5 percent of the fuel consumed by the five diesel configurations tested was converted to sulfate, measured by the dilution tunnel barium chloranilate method. The range was from 0.9 to 4.5 percent depending on engine and condition.

Exhaust $SO_2$ was found to account for the remainder of the fuel sulfur and permitted sulfur balances to be made within the normal ±10 percent of theoretical sulfur burned. The inaccuracy of the $SO_2$ measurement is greater than the amount of sulfur converted to sulfate making the measurement of $SO_2$ in future projects of minimal importance. The engine configuration apparently had no significant effect on the sulfate conversion.

PNA - Attempts at measuring polynuclear aromatic hydrocarbon, emphasized the need for additional procedural development. BaP was measured only on one of the HD engines, the DDAD 8V-71TA. Polynuclear aromatic hydrocarbons were measured by a different method on the Cummins and DDAD 6V-71 engines. The sampling and analysis of PNA's is in its early exploratory stage and is in need of a substantial amount of development before confidence in the quantitative rates can be established.

Light Duty Diesel Vehicles

Gaseous - All three Mercedes passenger cars had HC emissions well within statutory limits of 0.25 g/km (0.41 g/mi), while both the

Peugeot 204D and Perkins 6-247 were above the limit. All five vehicles were well below the statutory CO limit with the Perkins 6-247 about double the 0.6 of the three Mercedes cars. The Peugeot 204D with Comprex equipped Mercedes 220D were lower in $NO_x$ than previously tested diesel cars and approached the statutory limit of 0.25 g/km. All of these values were from vehicles without intentional emissions optimization. The Comprex equipped Mercedes 220D is an experimental adaptation.

Fuel Consumption - The superior thermal efficiency of the diesel cycle was illustrated by the five vehicles. For example, the three Mercedes cars had city estimates of 9.1 to 9.9 liters/100 km (25.9 to 23.8 mpg) and highway estimates of 7.0 to 7.8 liters/100 km (33.5 to 30.0 mpg). The Peugeot 204D (1134 kg, 2500 lbs test weight) had a city estimate of 6.7 liters/100 km (35.9 mpg) and a highway estimate of 5.4 liters/100 km (43.8 mpg). The heavier pick-up truck (2041 kg, 4500 lb test weight) powered by the Perkins 6-247, had city estimates the same as the Mercedes passenger cars and a highway estimate of 8.32 liters/100 km (28.3 mpg).

Smoke - From continuous recordings during various driving cycles, it was found that the exhaust opacity was at or near the threshold of visibility most of the time. Only during accelerations were there easily noticeable smoke discharges. The Comprex equipped Mercedes 220D had the highest opacity being quite noticeable, especially during the acceleration. The Comprex acted somewhat as a conventional turbocharger might in smoke behavior.

Particulates - Of the five vehicles, the Comprex equipped Mercedes and Perkins 6-247 had the highest particulate rates. This is consistent with the visible smoke discharge even though the smoke-particulate relationship at or below the threshold of visibility is not defined. Values ranged from 0.237 to 0.500 g/km over the FTP, 0.150 to 0.307 g/km for the SET and 0.185 to 0.335 for the FET. The lowest particulate rate was obtained with the smallest car, the Peugeot 204D, an overall average of 0.328 g/km, about twice that of a car operating on leaded gasoline. These are very rough and general comparisons to place diesel car particulate into some perspective.

The particulate from the Peugeot 204D was found to plug the plastic Fluoropore filters for sulfate collection during the run necessitating a change in flow rate during the test. Examination of the particulate revealed that the carbon fraction was much lower and the hydrogen content much higher than the other passenger cars. The apparent higher amount of hydrocarbon matter in the particulate indicates a greater amount of unburned or partially burned fuel and lubricating oil.

Sulfate - Sulfate ranged from 5.1 to 12.9 mg/km for the five cars by the three transient test procedures. On the order of 1.6 percent of the fuel sulfur was converted to sulfate during city driving cycles, 1.9 percent during the sulfate test cycle and 2.3 percent during the highway fuel economy test. The remainder of the 0.23 percent by weight sulfur in the fuel was apparently converted to $SO_2$.

It may be shown that for an average conversion of 20 percent of fuel sulfur to sulfate by catalyst and air pump equipped gasoline cars that the diesel contributes about half as much sulfate per kilometer driven. This is based on average sulfur content of 0.23 percent by weight for DF-2 and 0.03 percent for gasoline. The variability of sulfate emissions from catalyst cars make this rough comparison subject to improvement as better data becomes available.

Odor - Odor ratings at 100:1 exhaust dilution by trained panel indicated that the three Mercedes cars had about the same odor quality and intensity, in the range of "D"-2.5 to "D"-3, a moderate level yet quite noticeable. The Peugeot 204D and Perkins 6-247 had significantly higher odor levels, on the order of "D"-3.5 for the Peugeot and "D"-4 for the Perkins. These levels are moderate to strong and are easily noticed. Contrary to the HD engine experience, the odor ratings made during steady state were generally in the same range as the transient acceleration, deceleration, and cold start.

Overall, the relationship of DOAS to observed "D" rating was much better and more encouraging than found with the five HD engines. This was found for both steady state and transient cycle vehicle operation.

Aldehydes - A variety of aldehydes were found to be higher in concentration during the steady state odor test conditions from the Peugeot 204D and Perkins 6-247 than the three Mercedes cars. This was also true during the tests over the transient driving cycles in the case of formaldehyde and acetaldehyde. For the most part, the three Mercedes passenger cars reacted the same. Full scale testing to establish vehicle test repeatability has not been performed and therefore the results, especially during transient test cycles, should be used with caution. One thing is clear, however, and that is the higher aldehydes from the Peugeot 204D and Perkins 6-247 vehicles is consistent with the higher hydrocarbons, NRHC, particulate and odor from these two vehicles.

Noise - All four passenger cars had relatively low dBA noise levels. based on acceleration, cruise and curb idle interior and exterior sound level measurements. The Perkins 6-247 powered pick-up truck had higher exterior dBA ratings during the SAE acceleration test as well as curb idle. However, none of the vehicles would be classed as noisy with all measurements below 80 dBA. Compared to many gasoline powered cars, the diesel engine noise has a different quality sound, especially at idle.

Acceleration Performance - The minimum time to accelerate from 0-96.5 km/hr (0-60 mph) was with the Comprex equipped Mercedes 220D. The Mercedes 300D, Perkins 6-247 powered pick-up truck, Mercedes 240D and Peugeot 204D had next fastest acceleration times.

# II. INTRODUCTION

More and more, the diesel engine is considered a viable alternative to the conventional SI engine for automobiles. For many years, the diesel engine has dominated intercity trucking and both intercity and intracity buses. In these applications, the diesel has demonstrated a clear superiority over all other power plants in terms of fuel economy and durability. In recent years, a renewal of interest in mid-range diesels for use in urban delivery trucks has been evident. The basic reason given has been the superior fuel economy. This trend is expected to continue with the real possibility of diesel powered light duty vehicles (LDV's) becoming much more popular.

## A. Background

The Clean Air Act amendments of 1965 were specific in expressing concern over odor and smoke from diesel powered vehicles. This legislation prompted a long range investigation of diesel emissions which began in 1966 at Southwest Research Institute's Department of Emissions Research on behalf of the Environmental Protection Agency (EPA). This continuing activity, currently in its tenth year, has resulted in a large number of reports and papers on the subject.(1-5)* A number of other studies regarding diesel emissions were made by SwRI on behalf of EPA under separate projects.(6-25)

The original project was concerned with visible smoke and noticeable odor, both classed as "nuisance" emissions which interferred with the general welfare. Much was learned in how to measure odor and smoke and the types of conditions which would result in obvious discharges. In the intervening years, a steady broadening of this activity included unburned hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (now regulated emissions), methods of control and procedural development.

During the last few years, an increasing variety of non-regulated materials in diesel exhaust have come under scrutiny. Measurement of particulate, aldehydes, polynuclear organic matter, sulfate ($SO_4^=$), sulfur dioxide ($SO_2$) and several other contaminants have been investigated in an attempt to quantify emissions for which little data was available.

---

*Superscript numbers in parentheses refer to the List of References at the end of this report.

It is important to know as much as possible about the advantages and disadvantages of an alternative to the conventional gasoline engine as well as to document the emission rates from state-of-the-art diesel heavy duty engines. Thus, the justification for the work described in this report.

## B. Objective

The objective was to determine and compare the emissions from a group of five heavy duty diesel engines and from a group of five diesel powered light duty vehicles. The approach was to build on and use procedures and measurement methods perfected during the previous parts of this project. General emission measurement techniques had to be adopted from other EPA projects(27, 28), modified as necessary, and experience gained in their use. The principal "New" items to this project were particulate measurement, aldehydes by the DNPH method, sulfate by BCA method, $SO_2$ by the SwRI-BCA method, and PNA emissions. Thus the objective was not only to acquire emission values for a group of diesel cars and diesel engines but to bring into everyday use several measurement procedures for which little or only limited experience was available.

## C. Coordination Conference

On September 17, 1974 a conference was held in San Antonio to discuss the chemical measurement part of this project. The major concern of the meeting was the measurement of polyorganic matter (POM) as they relate to polynuclear aromatic (PNA) compounds. In attendance were Mr. Ralph Stahman, Mr. Dick Lawrence, Dr. Joe Somers, all of EPA Ann Arbor and Dr. Ron Bradow of EPA Research Triangle. Also discussed were the selection of suitable test fuels and the test conditions to be used. The tentative agreements reached are reported in Section II of this report.

Also reported in Section II are other discussions of specific importance that were made with the advice and at the consent of the Project Officer. The September 17, 1974 coordination meeting was in effect the first of many informal but none-the-less important actions of a coordination and project guidance nature.

## D. Acknowledgement

The Environmental Protection Agency selected and furnished the five diesel LDV's evaluated. The cars were provided to EPA for SwRI test program through the courtesy of the respective manufacturers. They were Mercedes-Benz of North America, Peugeot, and Perkins Company.

The three heavy duty engines and hardware for alternative engine configurations were obtained on "loan" from Detroit Diesel Allison Division, General Motors Corporation, and Cummins Engine Company. This project was conducted with the cooperation and assistance of these companies, for which we are very grateful.

# III. DESCRIPTION OF ENGINES, VEHICLES, FUELS AND PROCEDURES

This section describes the test engines and vehicles, fuels and their selection, test plan and procedures followed.

## A. Heavy Duty Engines

Table 1 lists particulars that describe the five heavy duty engine configurations studied. The Detroit Diesel Allison Division (DDAD) 6V-71 engine was operated with both Low Sac Needle size 60 (LSN-60) fuel injectors and B-60E injectors. The B-60E injectors are needle type with a constant end of injection helix instead of a constant start of injection helix. The Cummins NTC-290 engine was operated in a "current" configuration where the engine used standard static injection timing and in a "low" emissions configuration where variable injection timing was employed.

## B. Diesel Powered Light Duty Vehicles

Table 2 lists particulars that describe the five LDV's powered by automotive type diesel engines. All vehicles were delivered to SwRI by car carrier transport. The comprex-equipped Mercedes 220D is an experimental, one-of-a-kind, vehicle and is not a production unit.(26) The Mercedes 240D and 300D passenger cars are sold in the U. S.; while the Peugeot 204D, which uses a transverse mounted high speed diesel and front wheel drive, is not marketed in the U. S. The Perkins 6-247 engine was installed in the IHC Model 100 1/4 ton pick-up truck by Perkins Engine Company and evaluated as-received.

## C. Test Fuels

One area of discussion at the September 17, 1974 Coordination Meeting was that of test fuel and fuel sulfur level. Use of the standard smoke test fuel described in the Federal Register for this project could result in abnormally high emissions of those pollutants sensitive to fuel sulfur and aromatic content.

For example, the Federal Register smoke test fuel (also used for gaseous emissions testing for HC, CO and NO) must have 0.2 to 0.5 percent by weight sulfur. This higher-than-normal range of sulfur is intended to accelerate wear in the engine during the 1000 hour durability certification test. Since the fuel sulfur content will directly affect $SO_2$-$SO_4^=$ readings and indirectly affect odor ( the effect is uncertain), it was decided to use a sulfur level based on the 1973 Bureau of Mines survey results for automotive diesel fuel.

The higher-than-normal aromatics in the Federal emissions DF-2 fuel, because of its effect on smoke emissions, was considered

## TABLE 1. DESCRIPTION OF HD DIESEL ENGINES

| | | | |
|---|---|---|---|
| Engine Make | Detroit Diesel | Detroit Diesel | Cummins |
| Engine Model | 6V-71(1) | 8V-71TA(2) | NTC-290-C(3) |
| Engine Serial No. | 6VA53347 | X-470 | 10357839 |
| Strokes/cycle | 2 | 2 | 4 |
| Cylinder arrangement | V-6 | V-8 | I-6 |
| Displacement, liters | 6.98 | 9.31 | 14.01 |
| cubic inches | 426 | 568 | 855 |
| Compression ratio | 18.7:1 | 18.7:1 | 14.1:1 |
| Type Aspiration | Natural Blower Scavenged | Turbocharged Plus Blower | Turbocharged |
| Rated Speed, rpm | 2100 | 2100 | 2100 |
| Power at rated speed, kw | 163 | 269 | 216 |
| hp | 218 | 360 | 290 |
| Peak Torque Speed, rpm | 1200 | 1400 | 1400 |
| Peak Torque, N-M | 819 | 1383 | 1086 |
| lb-ft | 604 | 1020 | 801 |
| Typical Application | City Bus | Truck-Tractor | Truck Tractor |
| Typical Fuel Type | DF-1 | DF-2 | DF-2 |

---

(1) Tested with LSN-60 injectors at 1.484 timing and with B-60E injectors at 1.500 timing setting

(2) Aftercooled, N-75 injectors, 1000 hr durability engine

(3) Tested with standard timing, "current", configuration and with variable injection timing, "low", emission configuration

## TABLE 2. DESCRIPTION OF DIESEL POWERED LD TEST VEHICLES

| | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins[1] 6-247 |
|---|---|---|---|---|---|
| Model | 220D | 240D | 300D | 204D | IHC |
| Model Year | 1975 | 1975 | 1975 | 1974 | 1974 |
| Vehicle ID | COM-1* | 10066208* | 12019885 | 71-DTM* | 4H1 CODHB23906 |
| Type of Vehicle | Sedan | Sedan | Sedan | Sta. Wagon | Pickup |
| Number of Doors | 4 | 4 | 4 | 4 | 2 |
| Number of Passengers | 5 | 5 | 5 | 4 | 3 |
| Color | Blue | Brown | Brown | White | Blue |
| Odometer, km | 13,853 | 3,559 | 8,106 | 11,591 | 16,502 |
| Number of Cylinders | 4 | 4 | 5 | 4 | 6 |
| Displacement, litre | 2.20 | 2.4 | 3.0 | 1.36 | 4.05 |
| Bore, $m \times 10^{-2}$ | 8.71 | 9.1 | 9.10 | 7.8 | 9.2 |
| Stroke, $m \times 10^{-2}$ | 9.24 | 9.24 | 9.24 | 7.1 | 10.16 |
| Compression Ratio | 22:1 | 21:1 | 21:1 | 23.3:1 | 21:1 |
| Output Power, kw | 66 | 46.3 | 57.4 | 38 | 78.3 |
| at rpm | 3800 | 4200 | 4200 | 5000 | 3600 |
| Transmission Type | Man | Man | Auto | Man | Man |
| Speeds | 4 | 4 | 3 | 4 | 4 |
| Rear Axle Ratio | 3.46 | 3.69 | 3.46 | 4.06 | 3.75[2] |
| Tire Size | 175SR14 | 175SR14 | 645-14 | 145SR14 | H70-15 |
| Empty Weight (Scale), kg | 1500 | 1497 | 1588 | 953 | 1982 |
| Test Weight (Inertia), kg | 1588 | 1588 | 1814 | 1134 | 2041 |

---

*Per EPA Records.

(1) Installed in IHC series 100 pickup by Perkins

(2) Measured

and no decision made on whether to use the national average level or leave it at the minimum 27 percent specification. Not enough was known about fuel effects on many of the contaminants involved in this study to be able to give a clear recommendation at the September 17 meeting. There appears little justification, however, to continue using the Federal smoke test fuel for research into the variety of contaminants due to its atypical aromaticity and sulfur content.

It was decided to use the same test fuel in this project and another EPA Contract 68-03-2118 (Mr. Dick Lawrence, Project Officer), dealing with sulfates and $SO_2$ from a Mercedes diesel powered car. It was also decided to perform a brief study and analysis of fuel properties and their range and to use the 1973 Bureau of Mines diesel fuel survey(29) as a basis. To the extent practical, a commercially-available DF-2 fuel that meets these criteria was desired. Fuel sulfur level would then be adjusted by adding ditertiary butyl disulfide additive to achieve the national average sulfur content.

An analysis of data in the 1973 Bureau of Mines Survey(29) was made. The survey does not give national average values; and after some study, it was clear that true national average values must be sales weighted. In order to gain some approximations of national average values, the data from the five regions in the survey were arithmetically averaged. Thus, a kind of "national average" for each fuel property was obtained.

Table 3 lists the maximum, minimum and arithmetic average for the five regions for both city bus fuel and truck-tractor fuel. The average of the five U. S. regions surveyed was 0.096 percent by weight sulfur in city bus fuel (nominally a Type DF-1 fuel) and 0.228 percent by weight sulfur in truck-tractor fuel (nominally a Type 2-D fuel). This overall average value is not sales weighted nor is the individual regional averages sales weighted. Thus, these average sulfur levels must be used with much caution insofar as their true national average fuel sulfur content is concerned. The data on Table 3 were averaged from Tables 1 and 2, reproduced from Reference 29 and included in Appendix A. Also in Appendix A are Figures 2 and 3, reproduced from Reference 29, that show the trends of city bus (C-B) and truck-tractor (T-T) fuels.

In conversations with the Project Officer on January 9 and 10, 1975, it was agreed to use a commercially-available name brand Type DF-1 fuel for the test work on the 6V-71 coach engine. The reasoning was to use the type of fuel most nearly used by transit bus operators and to use the same type of fuel as used during the previous eight years of work with city buses. Over the years, a substantial data base and experience level has been accumulated with Gulf Oil DF-1 kerosene type fuel and it was appropriate to continue with this fuel.

Table 3 also lists the composition of EM-226-F, a DF-1 fuel,

### TABLE 3. SUMMARY OF 1973 BUREAU OF MINES DIESEL FUEL SURVEY OF CITY BUS AND TRUCK-TRACTOR FUEL PROPERTIES

| Test | ASTM | City Bus Fuel |  |  | DF-1 | Truck-Tractor Fuel |  |  | DF-2 |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Max. | Min. | Avg. | EM-226-F | Max. | Min. | Avg. | EM-176-F |
| Gravity, °API | D287 | 42.7 | 41.0 | 41.4 | 44.3 | 36.7 | 35.8 | 36.4 | 36.4 |
| Viscosity at 100°F |  |  |  |  |  |  |  |  |  |
| Kinematic, CS | D445 | 1.93 | 1.77 | 1.87 | 1.67 | 2.79 | 2.56 | 2.67 | 2.6 |
| Saybolt Univ., sec | D88 | 32.4 | 32.1 | 32.3 | 31.5 | 35.3 | 34.5 | 34.9 | 34.8 |
| Sulfur content, wt % | D129 | 0.130 | 0.050 | 0.096 |  | 0.251 | 0.192 | 0.228 |  |
|  | D1266 |  |  |  | 0.10 |  |  |  | 0.23 |
| Aniline point, °F | D611 | 149.1 | 146.8 | 147.8 |  | 148.3 | 142.7 | 145.5 |  |
| C residue on 10%wt% | D524 | 0.081 | 0.055 | 0.069 |  | 0.110 | 0.091 | 0.102 |  |
| Ash, wt % | D482 | 0.001 | 0.001 | 0.001 |  | 0.002 | 0.001 | 0.001 |  |
| Cetane number | D613 | 50.8 | 47.1 | 49.08 | Calc. | 48.7 | 46.9 | 47.9 | Calc. |
|  | D976 |  |  |  | 48.6 |  |  |  | 47.6 |
| Distillation temp. °F |  |  |  |  |  |  |  |  |  |
| Vol. recovered | D86 |  |  |  |  |  |  |  |  |
| IBP |  | 353 | 347 | 351 | 336 | 378 | 366 | 373 | 368 |
| 10% |  | 394 | 387 | 391 | 366 | 430 | 423 | 426 | 424 |
| 50% |  | 449 | 437 | 443 | 399 | 498 | 493 | 495 | 482 |
| 90% |  | 516 | 497 | 505 | 459 | 580 | 571 | 575 | 571 |
| End point |  | 556 | 537 | 544 | 511 | 624 | 613 | 620 | 623 |
| % Recovery |  |  |  |  | 99.0 |  |  |  | 99.0 |
| % Residue |  |  |  |  | 1.0 |  |  |  | 1.0 |
| % Loss |  |  |  |  | 0.0 |  |  |  | 0.0 |
| FIA, % | D139 |  |  |  |  |  |  |  |  |
| Aromatics |  |  |  |  | 15.1 |  |  |  | 25.6 |
| Olefins |  |  |  |  | 2.5 |  |  |  | 2.7 |
| Saturates |  |  |  |  | 82.4 |  |  |  | 71.7 |
| Flash Point, °F | D93 |  |  |  | 115 |  |  |  | 150 |

Note: The Max., Min., and Avg. Data are based on regional averages for the five U. S. regions in the 1973 Bureau of Mines Diesel Fuel Survey and are not Sales-Weighted averages.

and EM-176-F, and DF-2 fuel. Both are Gulf Oil Company commercial pump diesel fuels to which ditertiary butyl disulfide was added to achieve 0.10 and 0.23 percent by weight fuel sulfur levels, respectively. Although the DF-2 fuel (EM-176-F) happens to fall directly on the arithmetic average of the five U. S. regions surveyed in 1973, the DF-1 diesel fuel does not. The DF-1, the same as that used by San Antonio Transit System, is Gulf DF-1 kerosene, the same as Jet A fuel and is as close as any in the area to the "national average." EM-226-F is notably lower in endpoint and is a lighter fuel than the "national average" on Table 3. Cetane number and viscosity were quite close, however, to "national average."

During the January 10, 1975 discussions, it was mutually agreed to utilize both Gulf fuels; since they were readily available and not substantially different from the average fuel properties listed in Table 3. A substantial amount of test work and experimentation has been accumulated with both fuels over the years at SwRI on odor, smoke, and gaseous emissions. The DF-2 fuel was used on all engines and vehicles other than the DDAD 6V-71 city bus engine.

## D. Test Plan

The test plans are described briefly for each category of engines/vehicles evaluated.

### 1. Heavy Duty Engines

The five HD engine configurations were operated on a stationary engine dynamometer. This permitted acquisition of test data that is consistent with the Federal Test Procedure (FTP) for heavy duty diesel engines by (1) the 13-mode test for gaseous emissions and (2) the Federal smoke test for visible emissions. Thus, the data can be compared to Federal limits for HC, CO, NO (as $NO_2$) and smoke. The nonregulated pollutants could then also be expressed in units consistent with the 13-mode test; namely grams per kw-hour.

For the DDAD 6V-71 and Cummins NTC-290, the engines were run in their as-received standard configurations and then modified and the entire series of tests re-run. The injector replacement with the 6V-71 and the changeover from fixed injection timing to variable timing (NTC-290) was performed by SwRI staff with the advice and instructions of the respective manufacturer. In the case of the Cummins engine, it was necessary to have a service representative from the local Cummins Sales and Service branch to adjust the timing and provide other assistance.

Each series of tests began with the running of several, replicate, 13-mode FTP gaseous emissions tests followed by several Federal smoke tests. From this, the general performance of the engine could be assessed in terms of fuel consumption, air consumption and power output. The engine's smoke level and HC + $NO_2$ were then compared to standards and to previous data run either at SwRI or by the manufacturer. The next step in the series was to connect the exhaust to the dilution tunnel via a suitable muffler so that only a portion of the exhaust was diluted and the remainder vented. The dilution tunnel runs were based on seven modes of the 13-mode test and involved replicate runs for 47 mm fiberglass, Fluoropore and 8 x 10 size fiberglass. $SO_2$, sulfate, PNA, as well as particulate emission rates were then determined. The engine exhaust was then connected to the SwRI odor sampling dilution system for odor panel rating. During these replicate days of operation on each engine configuration, odor panel rating, diesel odor analytical system (DOAS) measurement, non-reactive hydrocarbons (NRHC) and aldehydes were measured as well as HC, CO, $NO_x$, $CO_2$ and selected engine parameters.

### 2. Light Duty Vehicles

All five LDV's were tested as a group in their as-received condition starting with replicate 1975 cold start Federal Test Procedures (FTP), sulfate emission test (SET) and highway fuel economy test (FET) for gaseous emissions and fuel consumption determinations. NRHC, aldehydes, and DOAS analyses were made of selected transient cycles. Next, smoke tests were performed using the EPA smokemeter with the three transient test cycles, FTP, SET and FET. The entire exhaust was then directed into a dilution tunnel and the FTP, SET and FET transient test series repeated to obtain emission rates of particulate, sulfate, $SO_2$ and BaP. Repeated runs were made to obtain 47mm glass and Fluoropore samples and 8 x 10 size fiberglass filter samples.

Next the vehicles were operated on the dynamometer adjacent to the odor room, and replicate odor evluations performed. Aldehydes, DOAS, NRHC, CO, $CO_2$, HC and $NO_x$ measurements were obtained simultaneously with the odor panel ratings. Then the vehicles were operated over the SwRI road course for sound level, noise, measurements. Last, each of the vehicles were driven to determine general performance during several maximum power "wide-open-throttle" accelerations.

## E. Procedures and Analysis

The specific test procedures and analysis systems used for each emissions category are described in the following subsections. In every case possible, recognized procedures published in the Federal regulations were employed. Instruments, sampling and analysis, and other facilities adhered strictly to these methods without exception. Where a Federal procedure did not exist, existing procedures for HD diesel vehicles were modified or adapted as necessary for purposes of this project. The advice and consent of the Project Officer was obtained on those areas of substantial modification before proceeding.

In general, the procedures and analytical efforts are the same as that used in previous projects in the long range investigation. Several new sampling and analytical techniques were utilized from a related project(27, 28) and a few such as DNPH and $SO_2$ - $SO_4^=$ for diesels for the first time.

### 1. 1974 Heavy Duty Gaseous Emissions FTP-HD Engines Only

The 1974 HD gaseous emissions test, known as the 13-mode test, is described in Reference 28 as a stationary engine test. The 130-minute long procedure is a speed-load map of 13 modes at 10 minutes per mode. In addition to CO and NO by NDIR (according to SAE recommended practice J-177), air rate must be measured continuously (according to SAE recommended practice J-244). A Flo-Tron system was used to measure the net fuel consumption of the engine. Exhaust hydrocarbons were measured by heated, 191°C (375°F), flame ionization detector optimized in accord with SAE recommended practice J-215.

The HD diesel engines investigated had a common rated speed of 2100 rpm. For the 13-mode test, the intermediate speed is defined as peak torque or 60 percent of rated, whichever is higher. The procedure starts with low idle, then 2, 25, 60, 75, and 100 percent load at intermediate speed followed by low idle. Then speed is increased to "rated" at 100 percent load with decreases to 75, 50, 25, and 2 percent. Another idle is then run. Figure 1 upper left view, shows the NDIR's for CO and NO and heated FID for HC used during the 13-mode test series.

Also shown in Figure 1 are views of the HD diesel engines mounted on two identical 500 hp dynamometer facilities. The upper right view shows the Cummins NTC-290. The center photos are left to right side view of the Detroit Diesel 6V-71. The 8V-71 TA engine was tested on the same stand as the 6V-71. The center right view shows a Merriam laminar air flow instrument attached to the engine intake and drawing air from a plenum which houses activated charcoal and particulate filters. The stationary 13-mode procedure uses measured power output at the flywheel to determine the cycle weighted power for division into the product of emission concentration times density of emission times flow of exhaust to get brake specific emission rate. The lower two photos of Figure 1 illustrates the 500 hp Midwest eddy current-type dynamometer and large inertia wheel arrangement used to simulate transient engine operation as well as absorb the power output.

The 13-mode tests were performed in replicate, usually two to three times and in strict accord with the Federal Test Procedure with the

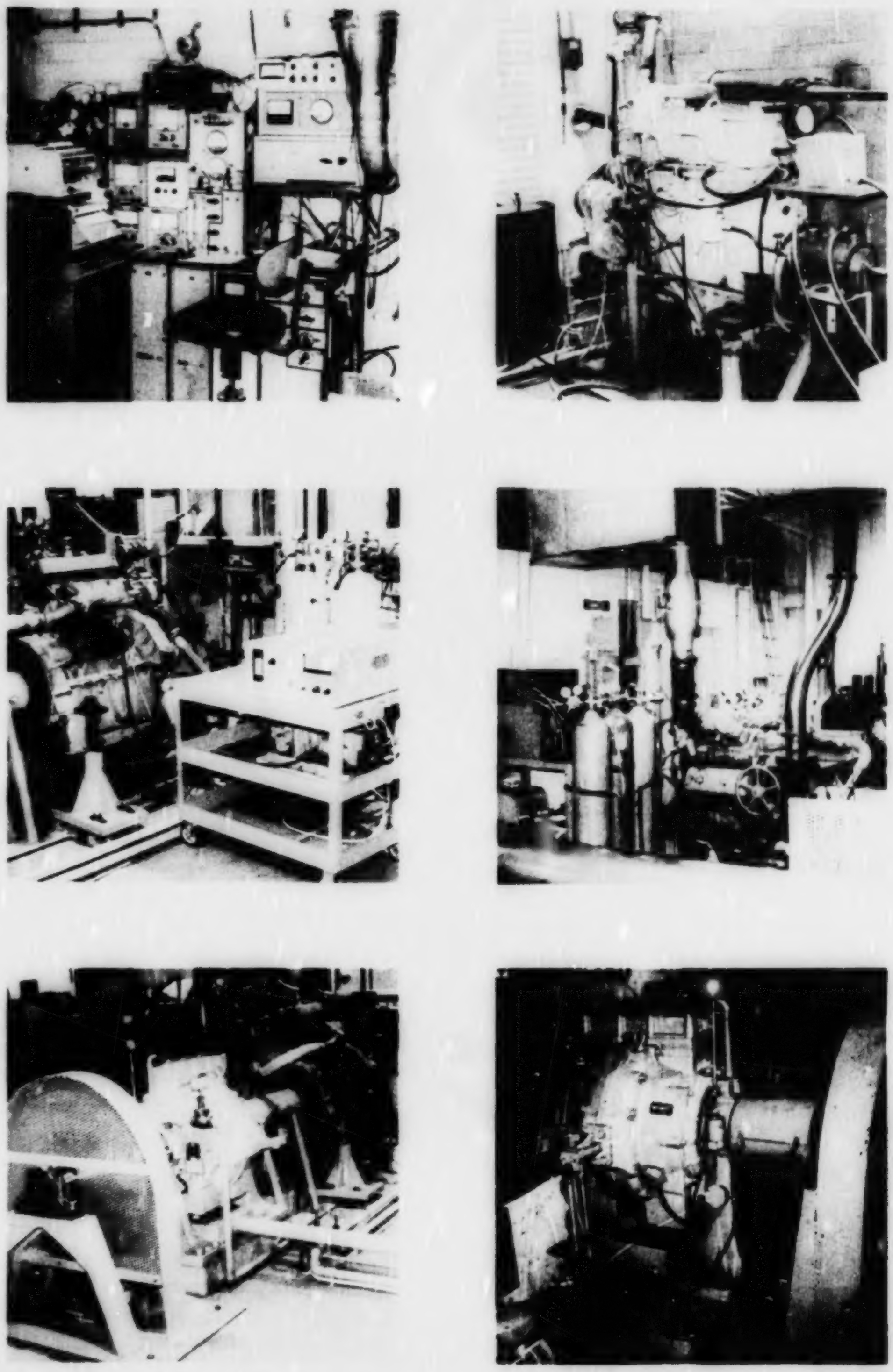


FIGURE 1. HD DIESEL ENGINES UNDER 13-MODE GASEOUS EMISSIONS FEDERAL TEST PROCEDURE

one exception of test fuel. The 13-mode tests were performed only with the five heavy duty engine configurations and were not run on the five diesel powered LDV's. Modal emissions data were taken on the five LDV's during the odor testing sequence. These modal values were obtained at speeds more indicative of actual engine-passenger car/light truck operation than the HD 13-mode test.

## 2. Smoke Test Procedures

Smoke tests were performed on both heavy duty and light duty type engines as follows.

### a. 1974 HD Diesel Smoke FTP - HD Engines Only

The Federal smoke test, promulgated in 1968 (Reference 30), was the basic smoke evaluation procedure utilized for the five HD engine configurations. It was improved and more stringent standards adopted in 1972(31) for 1974 certification purposes. Replicate smoke tests were made using the Federal HD smoke test, shown in the Figure 2 schematic. It consists of an initial engine acceleration from 150-250 rpm above the low idle speed to 85-90 percent of rated engine speed in 5.0 ± 1.5 seconds, a second acceleration from peak torque speed (or 60 percent of rated speed, whichever is higher) to 95-100 percent of rated speed in 10.0 ± 2.0 seconds, and (following this second acceleration) a full-power lugdown from 95-100 percent of rated speed to the particular intermediate engine speed (peak torque speed or 60 percent of rated speed) in 35.0 ± 5 seconds. Three of these sequences constitute one smoke test.

For each sequence, the average smoke opacity from the 15 highest-valued one-half second intervals of the two accelerations determine the "a" factor, and the average opacity from the five highest-valued one-half second intervals of the lugdown mode determine the "b" factor. The maximum values allowed for "a" and "b" factors of 1970 through 1973 certification engines were 40- and 20-percent opacity, respectively. For 1974, the "a" factor was reduced to 20-percent opacity and "b" factor was reduced to 15-percent opacity. The peak or "c" factor, which is the average of the three highest one-half second intervals per cycle, is determined from the "a" and "b" chart readings. The three cycle "c" values are then averaged to determine the "c" factor for the test. Smoke-power curves were obtained in which the engine was run in 200 rpm increments and smoke measured at full power throughout the range of operating engine speed. These full power smoke values give additional insight on steady state maximum smoke performance.

### b. Transient Smoke Tests - LDV's Only

There is currently no recognized U. S. smoke test procedure

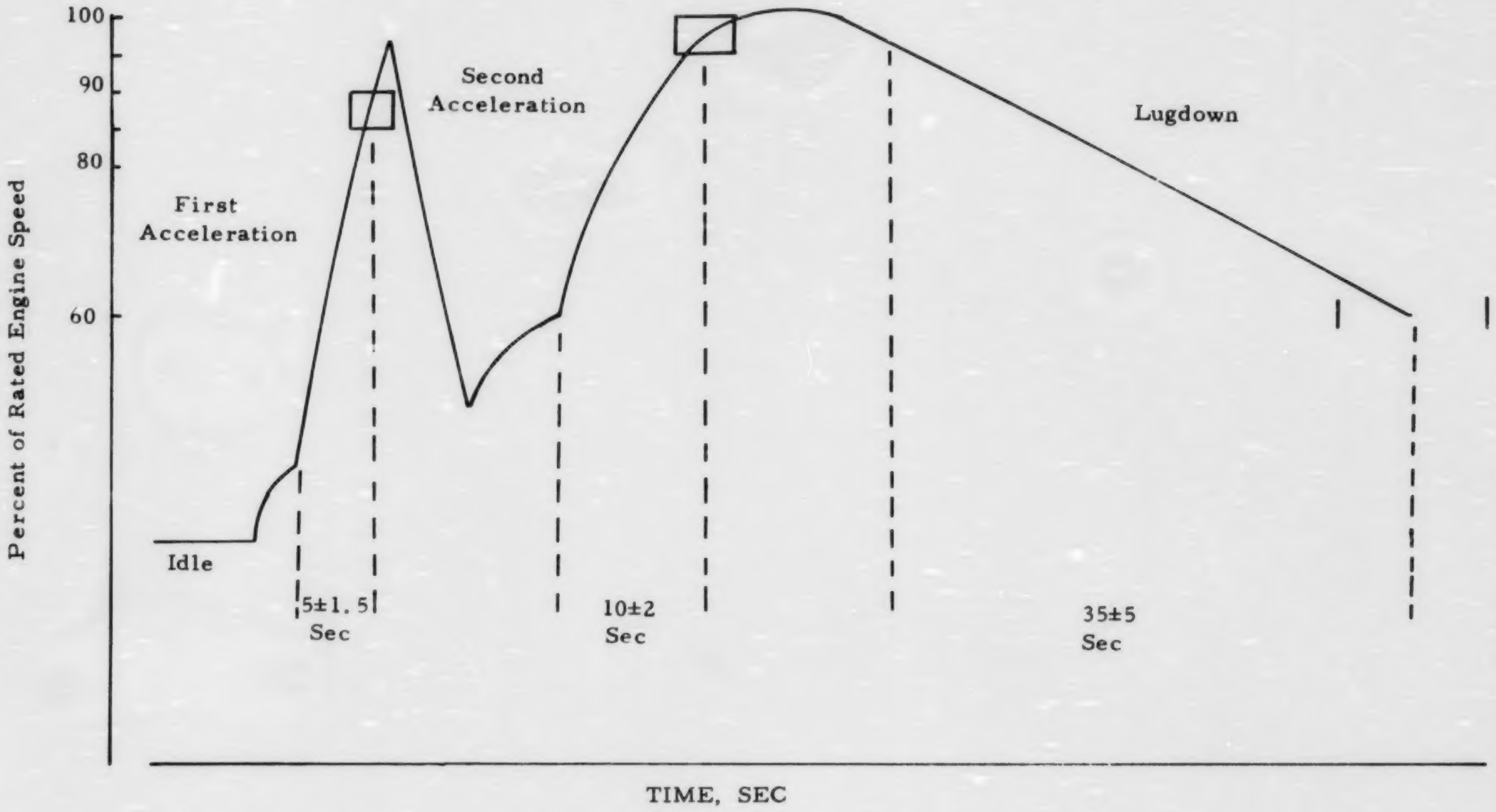


FIGURE 2. SCHEMATIC OF ONE CYCLE OF FEDERAL SMOKE COMPLIANCE TEST - ENGINE SPEED VS TIME

for light duty passenger car exhaust. Although the heavy duty schedule of speed and load versus time can be used with the light duty vehicle by a chassis dynamometer version of the test, it is uncertain whether this test is indeed representative of the way the smaller, higher speed diesels operate. Specifically, engine rated speed is considered higher than that normally encountered in passenger cars in urban use. The visible smoke emissions from the five LDV's were continuously recorded during operation of the vehicle over the three transient during cycle (FTP, SET, FET) but with the CVS disconnected. These cycles will be described in the next section.

The two top photos of Figure 3 show selected test cars as prepared for the smoke tests. Note the short 0.61 meter (24 inch) exhaust pipe extension of 50.8 (2 inch) exhaust pipe. The EPA smokemeter is mounted at the end of this pipe so that the centerline of the light beam is 127 mm (5 inches) from the tip of the pipe. The usual light duty water brake Clayton 50 hp chassis dynamometer with belt drive inertia system was employed. Figure 3 (center left photo) also shows the multi-pen strip chart recorder used to monitor smoke opacity, vehicle and/or engine speed. The usual driving aid was used to drive the transient LA-4, SET or FET speed versus time trace.

### 3. Transient Test Procedures - LDV's Only

The cold start 1975 FTP was the basic gaseous transient procedure used for the five diesel powered LDV's. This procedure was not employed with the stationary heavy duty diesel engines. It is essentially the same for both gasoline and diesel fueled cars. The basic gasoline procedure was described by Reference 31 and modified in more recent Federal Registers. The diesel procedure was originally described in Reference 32 and modified in later Federal Registers. Hydrocarbon values were obtained by the continuous hot flame ionization analysis.(9) All tests were on the same light duty chassis dynamometer with the same CVS and analytical train. The Federal Test Procedures for gaseous emissions were followed without exception. No evaporative hydrocarbons tests were made.

In addition to the usual HC, CO and $NO_x$ measurements, samples were continuously taken and collected in reagents for wet chemical analysis or in suitably packed traps for later odor analysis. These samples were withdrawn in the stainless steel pipe section connecting the exhaust dilution point (below the CVS filter box) and the CVS inlet. Several probes were inserted into this pipe section; one probe for the DNPH bubblers and one for each of the three odor trapping systems for the diesel odor analytical system (DOAS).

These probes were located adjacent to the probe used to obtain the continuous HC sample. All sample lines and interfaces were heated

FIGURE 3. GASEOUS AND SMOKE EMISSIONS MEASUREMENT FROM LDV's DURING TRANSIENT CYCLES

as required to maintain sample integrity for diesels. HC sampling and diesel odor analytical systems (DOAS) traps were taken at gas temperatures of 191°C (375°F). Aldehyde samples were obtained by use of large glass bubblers immersed in ice water.

A digital integrator was used to integrate the time-concentration signal from the HC analyzer, a flame ionization detector with linear response. The other continuous samples depended on their absorbing materials, reagent for wet collected samples, and chromosorb in the case of the diesel odor traps, to integrate a total representative sample for the entire 1975 FTP. It should be understood that each FTP included three separate bags for gaseous emissions. The integrator for HC was wired to give three separate integrations.

In the case of wet collected and odor traps, the entire 23-minute (Bags 1 and 2) and the third bag 505-second portion of the 1975 FTP were taken in a single collector (bubbler or trap). This was necessary to obtain sufficient sample for analysis and preclude the problem of switching after the first 505 seconds of the run (cold start bag).

All runs were made with the CVS main blower slowed to a nominal 5.38m$^3$ per minute (260 CFM). The reason was to prevent overdilution of the already air dilute exhaust and maintain the sensitivity of analysis. No problems were encountered by operating at this lower-than-normal speed once the CVS was calibrated and propane checked.

Figure 3 also shows various views of the test set-up used with the eight cars tested by the 1975 LD FTP. The driving aid strip chart, engine cooling fan, chassis dynamometer and variable inertia system are shown in the center right photo. The lower two photos of Figure 3 shows the arrangement of the items used to continuously monitor or sample the dilute exhaust for oxygenates, HC, and DOAS. Three ovens housed the systems. Each interface was separate and had its own set of controls, heated sample line or lines. The lower left view shows the DOAS trap interface and part of the HC oven relative to the CVS in the background. The lower right view shows the sample interface for oxygenates.

### 4. Odor and Related Instrumental Analyses - HD and LDV Engines

This subsection includes evaluation of odor by trained panel, the measurement of gaseous emissions and trapping-analysis of odor samples by the DOAS simultaneously with odor measurements.

#### a. Evaluation by Trained Panel

The EPA (PHS) quality-intensity (Q/I) or Turk kit method of evaluation of dilute samples of diesel exhaust odor(33) was employed to express odor judgements by the trained ten-person SwRI odor panel. The kit, shown in Figure 4, includes an overall "D" odor in steps 1 through 12, (12 being strongest) that is made of four sub-odors or qualities. These comprise burnt-smokey "B", oily "O", aromatic "A", and pungent "P" qualities each in a 1 through 4 intensity series, 4 being strongest. Special odor sampling, dilution, and presentation facilities(1, 2) for diesel odor research were developed ten years ago using design criteria obtained in field studies of atmospheric dilution of bus and truck exhaust. Horizontal exhaust at bumper height from a city bus was found to be diluted to a minimum reasonable level of 100:1 before being experienced by an observer. This dilution level was used in the odor test of both HD engines and diesel LDV's, although it is uncertain that this is the reasonable minimum dilution level from a diesel powered passenger car. References 1 and 4 describe the odor facility and References 2, 3, and 4 describe the development of procedures and operating conditions for research purposes.

Figure 4 shows a number of views of the test set-up used during odor testing. The top left view shows the odor kit and top right a view of the odor room and panel. The center views show the Mercedes 240D passenger car under test. The lower left view is of the driver's controls for the dilution and odor measurement signalling while the lower right view shows the Perkins 6-247 powered IHC pick-up under test.

### b. Test Conditions

Both steady state and transient vehicle operation were simulated for odor evaluation.

#### (1) Heavy Duty Engines

For the first time in the entire long range project, odor measurements were made from diesel engines operated on a stationary dynamometer (see Figure 1). In the past, only diesel powered trucks and buses have been evaluated. With the advent of large inertia wheels used in the Federal smoke test, it was decided to employ the same inertia wheels to simulate vehicle acceleration and deceleration.

Simulation of the seven steady-state conditions, that comprise each morning's odor test runs, was as easily accomplished on the stationary dynamometer as with the chassis dynamometer vehicles. The seven conditions, a curb idle in neutral, 2, 50 and 100 percent of maximum power at each of two speeds - intermediate and rated, are replicated three times in random order for a total of 21 runs. Thus, most of the same conditions used for gaseous emissions by the 13-mode test are used. In the case of the city bus engine, the DDAD 6V-71, the rated and intermediate engine speeds were reduced from the 2100 and 1260 rpm of the 13-mode test to 1600 and 900 rpm, speeds indicative of the general range typically encountered by buses in urban operation.

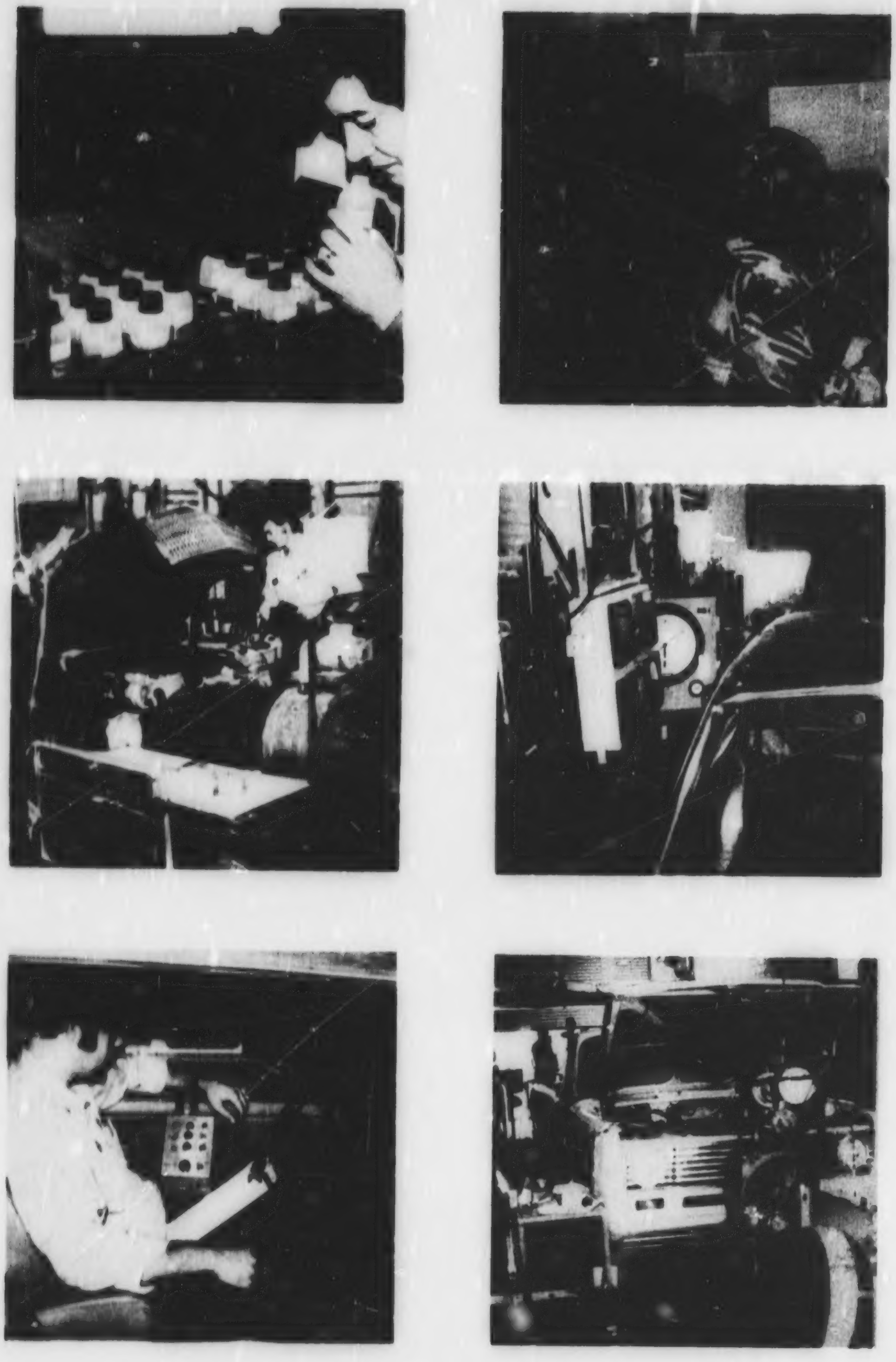


FIGURE 4. ODOR MEASUREMENT BY TRAINED SwRI PANEL

The afternoon runs included three conditions each replicated four times in random order. The acceleration after a prolonged curb idle is meant to represent the repetitive idle-accel of city buses and the acceleration in a low gear of large trucks. It was simulated by using the large inertia wheel without dynamometer pre-load and merely advancing the engine fuel control to the "full-rack" or maximum power demand position. The panel then rated the odor perceived during this rapid acceleration. Pre-test investigation revealed a specific time during the acceleration when maximum odor levels are produced.

Table 4 lists the times and engine condition when the odor was evaluated. The acceleration condition follows a brief cruise and is intended to simulate the upshift of a vehicle into a higher gear. It is performed at maximum "rack" or power position. The deceleration condition investigates the odor levels produced during the "closed-rack" no fuel demand position of the pump and simulates the deceleration of the vehicle from cruise. In both the accel and decel conditions, inertia and a pre-set dynamometer load was used to simulate the vehicle operation.

In all transient runs, the odor measurement was at a pre-determined point that produces the most noticeable odor level. The transients along with the steady state "odor map" provide a comprehensive evaluation of the engine's exhaust odor.

(2) LD Vehicles

The odor measurement procedures applied to the diesel powered cars was in keeping with that used in 1974(14, 15) and was based on the extensive previous work with diesel exhaust odor measurement from larger size vehicles. The basic philosophy was to characterize odor over a range of loads and speeds that could be encountered and over a wide enough range to cover steep uphill plus moderate trailer towing as well as the moderate load and no load conditions.

Table 5 lists pertinent operating data for each of the test conditions. The steady state runs were made at three power levels, normally zero, mid and high power at a high and at an intermediate speed. The seventh condition was a low idle of a well warmed-up engine. Mid-load was defined as a fuel rate midway between the fuel rates at full and no load (transmission in neutral). These seven conditions were performed in random order so as to replicate each condition three times for a total of 21 runs. Cold start odor ratings were taken with all cars.

In accord with the Project Officer, high speed was defined as the engine rpm corresponding to 90.1 km/hr (56 mph) level road load. All of the cars were in high gear or high range of the transmission, operating at approximately 3000 (2800-3500) engine

## TABLE 4. ODOR TEST CONDITIONS - HD ENGINES

| | DDAD 6V-71 | DDAD 8V-71TA | CUMMINS NTC-290 |
|---|---|---|---|
| | **Steady State Operation** | | |
| Engine Speed, rpm, High | 1500 | 2100 | 2100 |
| Inter | 900 | 1400 | 1400 |
| Idle | 440 | 480 | 610 |
| Kw @ High Speed, 100% | 116.4 | 252.7 | 214.1 |
| 50% | 58.2 | 126.4 | 107.1 |
| 2% | 2.3 | 5.1 | 4.3 |
| Kw @ Inter Speed, 100% | 72.1 | 193.2 | 162.9 |
| 50% | 36.0 | 96.6 | 81.5 |
| 2% | 1.4 | 3.9 | 3.3 |
| | **Transient Conditions** | | |
| Idle-Accel rpm start | 440 | 480 | 610 |
| end | 2100 | 2100 | 2100 |
| Odor Test rpm | 1200 | 1200 | 1400 |
| Accel Time, sec. | 4.1 | 4.3 | 4.0 |
| Accel range, rpm start | 900 | 1400 | 1400 |
| end | 1800 | 2100 | 2100 |
| Odor test rpm | 1500 | 1900 | 1900 |
| Accel time, sec. | 10.7 | 10.1 | 11.5 |
| Decel range, rpm start | 1600 | 2100 | 2100 |
| end | 440 | 480 | 610 |
| Odor test rpm | 1100 | 1400 | 1600 |
| Decel time, sec. | 6.8 | 7.5 | 7.7 |

---

Note: Power levels are nominal observed and varied slightly for DDAD 6V-71 and Cummins NTC-290 depending on configuration.

## TABLE 5. ODOR TEST CONDITIONS - LD VEHICLES

| | Mercedes 220D Comp. | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|
| | | | **Steady State Operation** | | |
| Engine High Speed, rpm | 2800 | 3000 | 2900 | 3500 | 2700 |
| Engine Inter Speed, rpm | 1680 | 1800 | 1740 | 2100 | 1620 |
| Engine Idle Speed, rpm | 760 | 710 | 640 | 750 | 670 |
| Fuel Rate High, high speed | 16.3 | 10.9 | 11.3 | 6.4 | 19.5 |
| (kg/hr) inter speed | 7.2 | 6.4 | 4.0 | 3.5 | 11.8 |
| Mid, high speed | 9.6 | 7.2 | 7.5 | 4.1 | 11.9 |
| inter speed | 4.2 | 3.9 | 2.0 | 2.1 | 6.8 |
| No, high speed | 2.9 | 3.0 | 3.7 | 1.8 | 4.4 |
| inter speed | 1.3 | 1.3 | 1.9 | 0.7 | 1.7 |
| Idle | 0.8 | 0.5 | 0.5 | 0.3 | 0.5 |
| Drive Gear, high speed | 4 | 4 | D-3 | 4 | 4 |
| inter speed | 4 | 4 | D-3 | 4 | 4 |
| Vehicle km/hr at high speed | 90.1 | 90.1 | 90.1 | 90.1 | 90.1 |
| inter speed | 51.5 | 53.1 | 53.1 | 53.1 | 53.1 |
| | | | **Transient Conditions** | | |
| Idle-Accel km/hr, start | 0 | 0 | 0 | 0 | 0 |
| end | 29.8 | 32.2 | 31.4 | 32.2 | 32.2 |
| Driven in | 1 | 1 | D-1 | 1 | 2 |
| Odor Test rpm | 3060 | 3320 | 3150 | 3650 | 2380 |
| km/hr | 24.1 | 24.1 | 24.1 | 24.1 | 24.1 |
| Accel time, sec. | 4 | 3.5 | 3.5 | 4 | 3.5 |
| Accel range, km/hr start | 32.2 | 48.3 | 40.2 | 32.2 | 40.2 |
| end | 80.5 | 80.5 | 80.5 | 72.4 | 80.5 |
| Driven in | 3 | 4 | D-3 | 3 | 4 |
| Odor Test rpm | 3240 | 2430 | 3170 | 3780 | 2200 |
| km/hr | 72.4 | 72.4 | 72.4 | 64.4 | 72.4 |
| Accel time, sec. | 9.0 | 9.1 | 7.5 | 15 | 11.0 |
| Decel range, km/hr, start | 80.5 | 80.5 | 80.5 | 80.5 | 80.5 |
| end | 48.3 | 48.3 | 48.3 | 40.2 | 48.3 |
| Driven in | 3 | 4 | D-3 | 3 | 4 |
| Odor Test rpm | 2550 | 1920 | 2800 | 2860 | 1720 |
| km/hr | 56.3 | 56.3 | 56.3 | 48.3 | 56.3 |
| Decel time, sec. | 11.0 | 10.5 | 9.6 | 11.0 | 13.5 |

rpm at 90.1 km/hr (56 mph). The intermediate speed was then defined as 60 percent of this speed, which was a nominal 1800 (1620-2100) rpm for most cars operating in the same gear or drive range resulting in an intermediate vehicle speed of 53 km/hr (33 mph).

In the afternoon, an acceleration after upshift, a deceleration after a cruise, and an acceleration after idle, from rest, were run. These three transients were replicated in random order four times, for a total of twelve transients per afternoon. In practice, the level road load, defined for a specific car test weight given in the Federal Register, was set in the dynamometer at 80.5 km/hr (50 mph). This road load plus an appropriate sized inertia wheel was employed to simulate the acceleration and deceleration performance of the vehicle.

The idle-acceleration test condition, an acceleration after prolonged 1 minute idle, normally involved evaluation during a rapid wide-open throttle (WOT) acceleration in low gear. The odor was evaluated at nominally 24.1 km/hr (15 mph), 2380-3320 rpm which was reached at 3.5 to 4 seconds after start of the acceleration.

The acceleration test condition was generally made in high gear after upshift and began at about 24.1 - 40.2 km/hr (15-25 mph). The acceleration ranged in time from 7.5 to 15 seconds depending on car performance. The deceleration was from 80.5 km/hr (50 mph) to 40.2 to 48.3 km/hr (25 to 30 mph) with evaluation at 48.3 - 56.3 km/hr (30 to 35 mph) about 9.6 to 13.5 seconds after closed throttle (CT). In all transients, the LD FTP road load was preset in the water brake dynamometer at 80.5 km/hr (50 mph).

### c. Gaseous Emissions

Gaseous emissions were also taken during the steady state speed-load odor maps. Measurements included HC by heated FID, $CO_2$, NO and CO by NDIR, NO and $NO_x$ by chemiluminescence (CL), oxygenates, and various NRHC. The seven conditions, in triplicate (21 runs) were repeated on two mornings normally separated by one day for analysis and preparation.

These measurements were intended to define the steady state performance and characterize emissions beyond that possible from the LDV transient procedures and the 1974 HD FTP 13-mode test. Also, the data would be useful in comparison with and correlation to the odor panel ratings and other measurements by the CAPE-7 DOAS instrument. Figure 5 shows a number of photos of the gaseous emissions instruments, equipment, and analytical equipment utilized in this category of tests. The two top photos show the emissions cart and heated HC oven.

### d. Partially Oxygenated Compounds - DNPH

Acrolein, aliphatic aldehydes, and formaldehyde, three

FIGURE 5. GASEOUS EMISSION, DOAS AND DNPH SAMPLE TRAPPING DURING ODOR EVALUATION

partially oxygenated materials, were originally planned to be obtained using the chromotropic acid method for formaldehyde, 3-methyl-2-benzothiazolone hydrazone (MBTH) method for aliphatic aldehydes, and the 4-hexylresorcinal method for acrolein. These wet chemical methods were employed for many years in previous odor correlation and characterization studies for EPA. References 3, 5, 6, 10, 12 and 14 are all major final reports under the long range study of diesel exhaust and contain data by these methods.

In January 1975, the Research Triangle Laboratories of EPA reported that use of the chromotropic acid method for formaldehyde and the MBTH method for aliphatic aldehydes give generally low results due to a positive interference of oxides of sulfur on the absorption readings. Both chromotropic acid and MBTH are wet chemical methods that depend on wet collection of a gaseous sample over a finite time period followed by several intermediate steps with a color development for detection by a Bausch & Lomb Spectronic 20 colorimeter.

Because of the uncertainty over the amount of interference, it was decided, after some discussion with the Project Officer and Dr. Joseph Somers of EPA, to employ the 2, 4-dinitrophenylhydrazine or DNPH method. This method was used by the Petroleum Research Center of the Bureau of Mines (Bartlesville) some years earlier with some success, but only with substantial effort. In the past, the partial oxygenates were obtained at SwRI for their use in predicting or correlating to perceived odor and for little other reason. They have never been reported as absolute values nor has their methodology been investigated.

In discontinuing the rather routine and simple collection and determination of oxygenates, there ensued an extended period of preparation and calibration. As a consequence, partial oxygenate measurements were not made of the HD engines. The DNPH method, as described by the procedure in Appendix A, was obtained from Dr. Ronald Bradow of EPA-RTP. Different collection traps are used, a GC is employed and there are many additional intermediate steps in the preparation of the sample once collected relative to the previously used methods. The more difficult to perform DNPH method resulted in fewer samples than previously analyzed.

Instead of the usual 21 samples, seven separate samples were obtained. Each sample contained the three replications and represented 12 to 15 minutes of sample absorption in the glass bubbler trap system with 4 to 5 minutes of trapping each run. The seven runs were made on the first day of the two day sequence for each vehicle. No samples were obtained from the five HD engines due to the delay required to prepare the DNPH system for use. All five diesel LDV's were, however, sampled and analyzed for partial oxygenates by the

DNPH method. Figure 3 (lower right view) shows a partial view of the traps and Figure 5 (center left photo) shows the chromatograph and some of the standards and reagents employed.

### e. Characterization of Light Hydrocarbons

The measurement of a variety of light hydrocarbons was performed using a gas chromatograph procedure developed by EPA (RTP).(34) This procedure uses a single flame ionization detector with a multiple column arrangement and dual gas sampling valves. The timed sequence selection valves allow for the baseline separation of air, methane, ethane, ethylene, acetylene, propane, propylene, benzene and toluene. Only methane is considered non-reactive. Ethane, propane, benzene and acetylene are considered reactive even though only to a small degree. Propylene, ethylene and toluene react to form photochemical smog.

Samples were obtained directly from the bag samples of FTP, SET and FET transient LD cycles and 7-modes used during all odor testing and analyzed. Individual values were determined for the bag or run. A detailed description of the individual columns, temperature, flow rates, etc., may be found in Reference 34. The center right photo in Figure 5 illustrates the analytical instrumentation that was used for this analysis.

### f. Diesel Odor Analytical System

As one result of approximately five years of research, sponsored under the CAPE-7 project of CRC APRAC, A.D. Little developed a prototype liquid chromatograph for use in predicting diesel exhaust odor. Called DOAS for diesel odor analytical system, the system provides two results, one being an indication of the oxygenate fraction called LCO for liquid chromatograph oxygenates, and the other called LCA for liquid chromatograph aromatics. These were found by earlier research by ADL to represent the major odorants in diesel exhaust. The ADL studies had shown a correlation of the TIA (total intensity of aroma) to sensory measurements by the ADL odor panel. TIA is equal to $1 + \log_{10}$ LCO.

Both LCO and LCA are expressed in micrograms per liter of exhaust using either the test fuel or a reference component for calibration. The LCO is, by virtue of its use to express TIA, considered the most important indication of diesel exhaust by this method. An entire series of reports have been published by ADL describing their work with diesel odor.(36-40) Reference 40 describes the DOAS and its use, while Appendix C in this same reference describes the sample collection procedure. Rather than repeat these instructions, this section will describe how the system was employed in this series of tests.

Until the prototype was furnished SwRI, one of the first three built by ADL, the DOAS had been limited primarily to in-house ADL development tests. Their work was based on a Detroit Diesel 4-71 engine-generator set. Although several fuels and injectors were tried, these tests of a direct odor panel-DOAS type were limited to the single exhaust odor source. Tests by Caterpillar with their in-house DOAS and samples from Cummins and Detroit Diesel, as a part of the CAPE-7 project, had indicated the potential of the DOAS to work with exhaust from a variety of engines.

With the availability of this potentially useful odor prediction method, it was decided to obtain simultaneous DOAS values with the trained SwRI odor panel on all vehicles in the previous work of this series(14, 15) and to continue its use on all vehicles and engines in this project. Recall that the DOAS does not measure odor, but measures a class of odorants.

Also, the prototype development by ADL had concentrated on the liquid chromatograph and the electronic integration and calculation of the LCO value to give a direct read-out of TIA based on a dialed-in sample volume. Little had been done on the specific sampling and trapping methods for collection of the sample except in the broadest general terms of sample flow, temperature, and time. Therefore, one of the first requirements of the previous project was the design and fabrication of a suitable interface, beginning with the sample probe and extending to the preparative or analytical trap. This system and its application was described in detail in the final report(14) of the previous project.

To obtain DOAS samples requires each test mode to be extended. Double the running time, from a nominal three minutes to six minutes, was needed to allow up to five minutes of trapping. The first minute is to achieve a stable operating speed and load. Panel evaluation is normally during the third minute of the run. No serious problems of tire or engine overheating were encountered with this schedule.

The sampling interface system, shown by the center left photo in Figure 5 follows good laboratory practice as applied to diesel hydrocarbon measurement. Most of the sampling system was housed in an oven held at 190°C (375°F). Each system, of which three separate ones are available, began with a multi-opening stainless steel probe located in the exhaust stack. This is normal practice for HC measurement from HD diesel engines. The sample was then transferred to the oven via a 9.5mm (3/8 inch) diameter stainless steel line 0.75m (30 inches) long covered by tubular exterior electrical heating sleeves to maintain 190°C (375°F) sample gas temperature. Between the probe and sample transfer line, a high temperature bellows type stainless valve was placed for leak check purposes. Inside the oven, the sample passed through a fiberglass filter, then into a square head welded metal bellows (stainless) pump head mounted inside the oven.

Immediately as the flow exits the oven wall, the DOAS trap is mounted so that it is accessible for change but is not located where the sample could have intentionally cooled. A number of traps are shown in Figure 5 (center right photo) ready for installation. Once the sample passes through the trap, the sample goes through a drierite column, a glass tube flowmeter, and then into a dry gas volume meter. The dessicant removes troublesome water which condenses in the flowmeter and gas meter. The flowmeter allows monitoring of gas flow, by visual observation, during the test while the gas meter measures the total flow of gas during the test run.

The effect of these temperature and flow variables singly and in combination on trapping efficiency remain to be determined. The exact temperature, flow rate and sample time given the trap proper is of some concern. For example, it currently begins at room temperature and then warms-up significantly during the five minute sampling time as more and more hot sample is handled. The definition of sample volume necessary for the DOAS understandably depends on concentration of odorous contaminants. Using the sampling procedure in Appendix C of Reference 39, the best sustained flow possible using the specified model 155 Metal Bellows pumps was about 5 l/min.

In the case of the cars operating on the 1975 FTP transient LA-4 test, it was estimated that the long sampling time of 31.4 minutes would compensate for the intentionally diluted (estimated 5 to 7:1) exhaust by the CVS method. Recall the dilution level was held to a minimum to prevent over-dilution of the already air-rich diesel exhaust. An improvement to the system would be the specification of a maximum trap exit gas temperature. It is understood from A. D. Little that above a certain exit gas temperature, the trap can lose efficiency. Presently, the exit gas temperature is not monitored and it may have a bearing on those tests in which very long sampling periods are required, such as during the 31.4 minute transient LD cycle. This is not considered a problem for the 5 minute trap time for raw exhaust.

### 5. Particulate

The mass rate of emission of particulate from both HD engines and LDV's were determined by collecting a known amount of particulate matter on a pre-weighed glass fiber filter. The 47 mm diameter Gelman Type A glass fiber media was the principal size and type of filter disc employed. Particulate mass rates were also obtained using both an 8 x 10 size fiberglass filter for polynuclear aromatic (PNA) compound analysis and by Fluoropore (Millipore Corp.) 47mm plastic filter media with 0.5 micron mean pore flow size. The Fluoropore filters were used for sulfate collection.

The basic technique for sample collection was to dilute the exhaust with prefiltered air much the same as the constant volume sampler does with the exhaust in the LDV-FTP for gaseous emissions. The definition of particulate was in terms of the dilution and collection media and, importantly, the temperature at the point of filtration. In keeping with EPA definition of diesel engine particulate from Reference 27, anything that was collected on Type A glass at a temperature not to exceed 51.7°C (125°F) and not condensed water was considered diesel particulate. The particulate thus included aerosols and unburned fuel-like matter. Most tests were made at lower average temperatures and depended on the exhaust volume, temperature, and dilution level.

The nominal 0.457 m (18 inch) diameter by 4.88 m (16 ft) long dilution tunnel used to dilute and cool the exhaust is shown in the Figure 6 schematic drawing. The pertinent dimensions, flows, velocities, and the relationship of the various components which make up a particulate collection system are indicated. A micro balance, with 1 microgram accuracy and housed in a special humidity, temperature controlled environment, was used to weigh the filters before and after the test. The weighing box is supplied with pre-filtered scrubbed air at a constant 22.2 ± 0.6°C (72 ± 1 °F), 10.6 ± 0.3 g/kg (74 ± 2 grains/lb dry air) humidity at 0.3 $m^3$/hr (10 CFM).

### a. LDV Particulate

The dilution tunnel was quite capable of handling the entire exhaust from all five of the diesel powered LDV's without exceeding the 51.2°C (125°F) sample temperature. The dilution tunnel nominal flow of 14.15 $m^3$/min (500 CFM) was not excessive in overdiluting necessarily but is greater than would normally be used in a gaseous emissions test by conventional CVS technique. The particulate tests were performed separately from the gaseous emission tests and used the same tunnel as in the HD engine testing.

In order to achieve a sufficient sample and because there is no convenient means to switch particulate samples at the 505 second point in the city driving schedule, all cold start FTP's were for the entire 23 minutes on a given filter. The ten minute soak period was then observed and then an additional full 23 minute city driving cycle repeated from a hot start. The other two transient driving cycles were from a hot start with the sample for the SET and for the FET collected on separate filters.

The four sample systems permitted the collection of two (2)

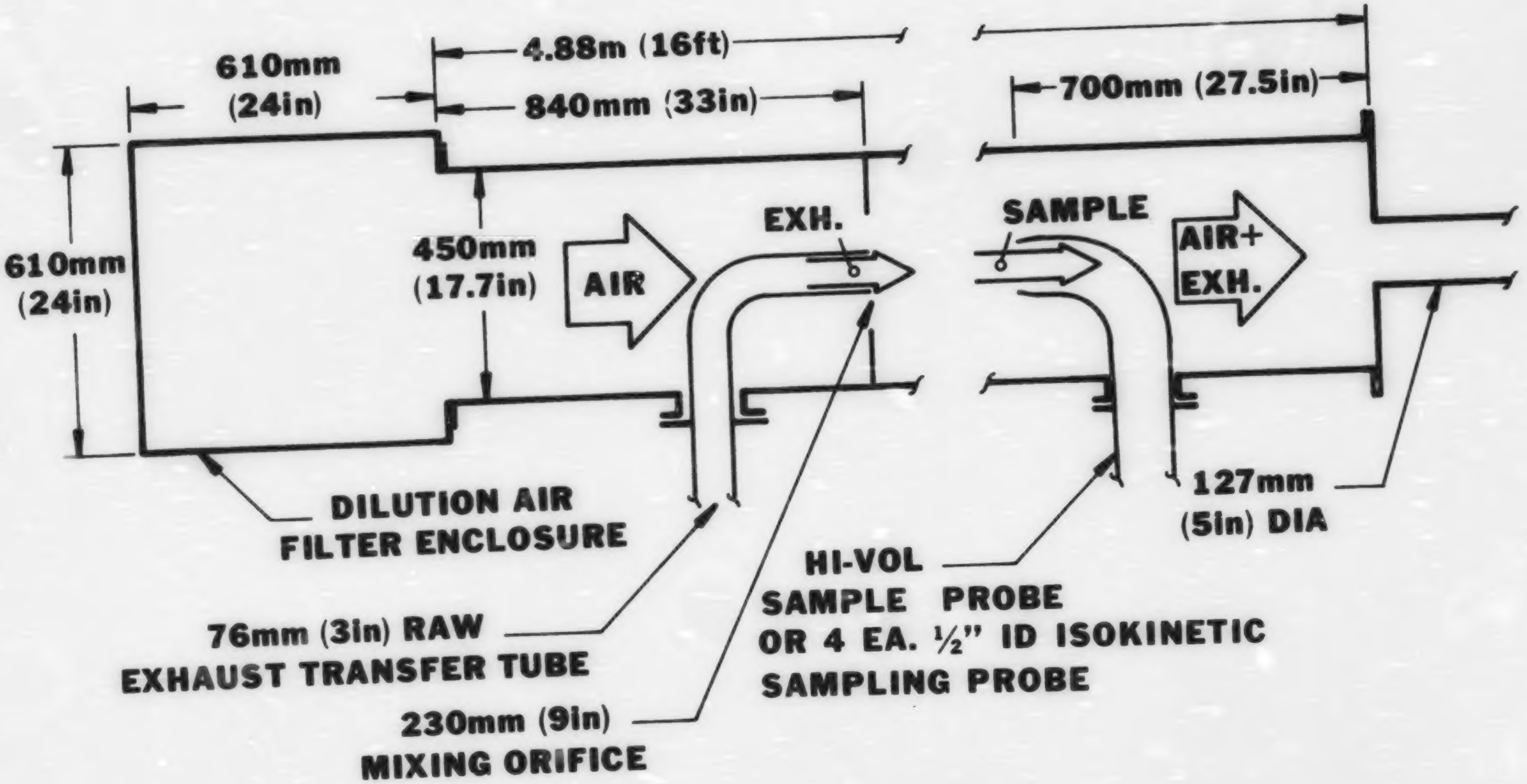

610mm
(24in)
4.88m (16ft)
840mm (33in)
700mm (27.5in)
610mm
(24in)
450mm
(17.7in)
AIR
EXH.
SAMPLE
AIR+
EXH.
DILUTION AIR
FILTER ENCLOSURE
76mm (3in) RAW
EXHAUST TRANSFER TUBE
230mm (9in)
MIXING ORIFICE
HI-VOL
SAMPLE PROBE
OR 4 EA. ½" ID ISOKINETIC
SAMPLING PROBE
127mm
(5in) DIA

FIGURE 6. SCHEMATIC SECTION OF DILUTION TUNNEL FOR DIESEL PARTICULATE SAMPLING

each particulate samples on 47 mm glass and two (2) each sulfate samples on 47 mm Fluoropore media. The testing sequence of cold-hot FTP, SET and FET was repeated on several successive days. This test sequence was then performed with the high-vol sampler to obtain larger amounts of particulate for PNA analysis using the 8 x 10 size glass filters.

The only difficulty encountered was with the Peugeot 204D. This vehicle, with the smallest displacement of all engines tested and with the lowest exhaust volume per cycle, would plug the Fluoropore filters near the end of the cold start FTP and early in the hot start FTP. The visual appearance of the particulate was such as to suggest an oily substance that apparently penetrated into the openings of the filter and completely blocked passage of the sample. The odor of the substance was similar to crankcase blowby gases and suggested a possible oil control problem. Smoke tests were re-performed and the visual appearance evaluated to determine if the engine had begun "burning oil". No change in the exhaust appearance was found nor was there any trace of blue smoke or oil burning. Oil consumption, which had been monitored by daily check of the engine dipstick level, remained negligible.

At the time of this difficulty, September 12, 1975, Mr. R. Lucki and Mr. J. Marty of Peugeot were visiting SwRI regarding this project. The problem of filter plugging was discussed in detail and the Peugeot staff were asked if they had noticed this before. The Peugeot research on particulates was reported to be just beginning and no data was available. Mr. Lucki and Mr. Marty then test drove the car to make certain performance was satisfactory and it was. At their request, the oil was changed and a new oil filter installed. No other maintenance was performed. To permit operation of this vehicle in the test plan, a pair of special isokinetic sample probe tips were machined in which the ID was changed to 0.00813 m (0.32 inch) from the usual 0.0127 m (0.5 inch) probe tips. These new tips resulted in a lower sample rate and permitted the Fluoropore filters to run the entire cycle without plugging.

The above described observation was carefully documented to both Mr. Ralph Stahman and Mr. Jack Mc Fadden by telephone, as it occurred, since it was unusual relative to the other four LD vehicles. The smaller probes allowed the test plan to be completed without incident. Tests made with the larger probes after oil and filter change indicated that the condition of the lubricating oil had no noticeable effect on the plugging since it still happened.

The various photographs in Figure 7 show the dilution tunnel in use with the Mercedes 300D car. The dilution tunnel was located alongside the car, as shown in the upper left and center left views. The positive displacement blower and the four sampling filter system is shown in the upper and center right views. The two lower views illustrate the insertion of the four probe assembly and the larger single 8 x 10 sample unit into the tunnel.

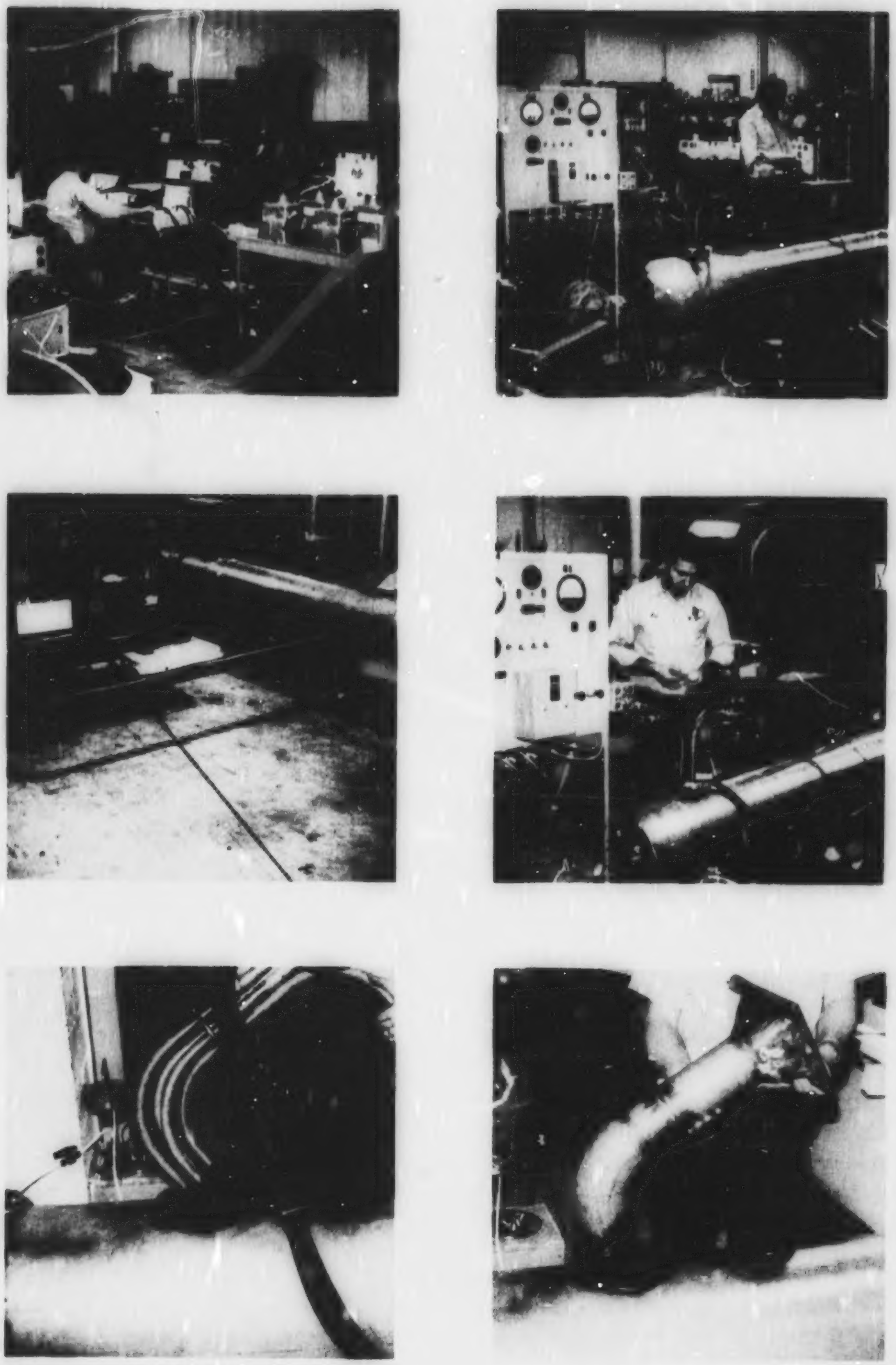


FIGURE 7. LDV PARTICULATE EMISSION MEASUREMENT

### b. HD Engine Particulate

The large volumes of hot exhaust from the diesel engines used in trucks and buses preclude the practical dilution of all the exhaust in a laboratory size dilution tunnel. This was recognized at the outset of SwRI's initial efforts to characterize particulates for EPA under Contract 68-02-1230 for RTP. In order to use the fairly standard EPA design 0.457m (18 inches) tunnel, an exhaust flow splitting system was devised whereby only a part of the exhaust is used in the tunnel and the remainder vented to the atmosphere. Obtaining a true split of the exhaust is a difficult job and even more difficult is knowing how much of the exhaust is split and diluted by the tunnel. With much care and attention to detail, this can be done with reasonable accuracy and repeatability.

After review of several possible flow splitters, it was determined that the vehicle exhaust muffler was the most realistic point to obtain a split of the total exhaust that retained all of the properties and characteristics of the bulk exhaust. Adjacent to the usual exhaust outlet from the conventionally-used stock muffler, a second but somewhat smaller outlet was added. As with the stock muffler outlet, an open-ended tube with the same length and wall perforations, diameter and pattern was fabricated and inserted inside of the muffler in a similar fashion to the stock outlet tube. By trying several size tubes, the exhaust flow could be matched to the filter temperature for given operating conditions of the test sequence. The use of a "sampling tube" within the muffler of similar design to that for the stock outlet was thought to give the exhaust a similar opportunity to flow out either tube and thus preserve the integrity of the sample.

The use of a large gate valve on the vented exhaust flow allowed the use of slight exhaust system backpressure so that some measure of control was available. The exhaust backpressure was generally set at or slightly below the engine manufacturer's maximum allowable at rated speed and load, as in the 13-mode FTP. At other speeds and loads, the back pressure was allowed to decrease to a value consistent with lower engine speeds and exhaust flows.

The exhaust sampling and dilution system was, for the heavy duty engines, identical to that described in References 27 and 28. For the NTC-290, a truck muffler was used and for the 6V-71 coach engine, a city bus muffler was used to effect the sample split. It is shown pictorially in Figure 8 for the heavy duty engines. The top left photo is of the tunnel alongside the DDAD 8V-71TA and shows the particulate and charcoal filtered intake system. A close-up of the exhaust system and muffler-splitter arrangement is shown in the upper right view of Figure 8. Notice the large gate valve used for backpressure and dilution level control.

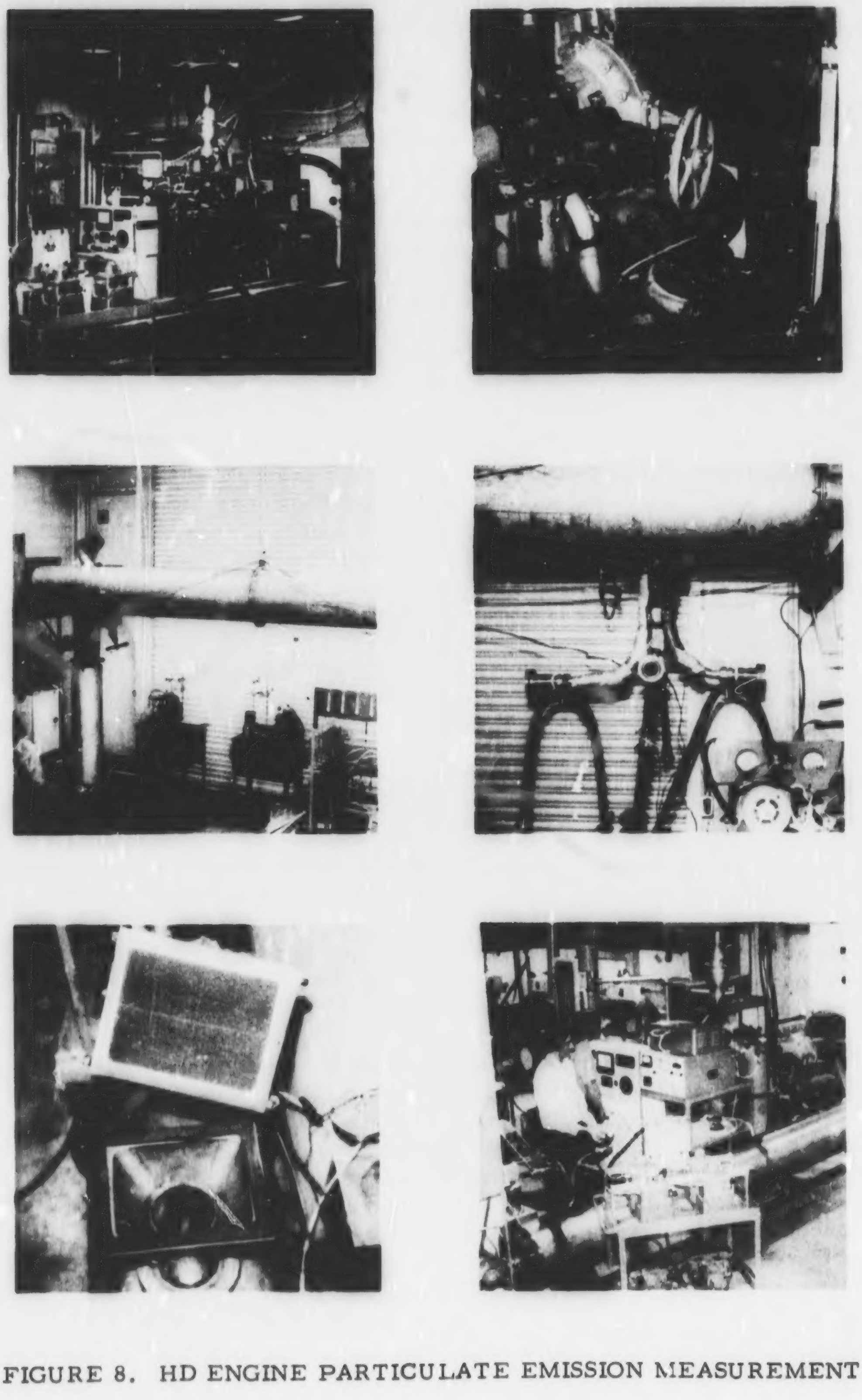


FIGURE 8. HD ENGINE PARTICULATE EMISSION MEASUREMENT

The center two photographs of Figure 8 show the tunnel used with the NTC-290 engine. A large truck muffler is shown vertically under the tunnel in the left view. Part of the exhaust then enters directly into the tunnel and filter samples are taken downstream in the right view. The lower views show the large 8 x 10 size and the small 47 mm size filters being removed after a run.

In both situations, the amount of exhaust that was eventually diluted and from which the particulate samples were obtained, was based on direct, continuous measurement of the $NO_x$ in the raw exhaust and in the diluted exhaust. The diluted exhaust measurement was corrected for ambient $NO_x$ to compensate for background. This normally was a negligible correction and was not made to the raw exhaust because of the uncertainty of engine combustion on trace levels of intake $NO_x$. The dilution ratios typically varied from about 10 to 18 parts of diluent air to 1 part of exhaust, the higher ratios needed with the higher temperature exhaust.

For purposes of this project, it was decided to obtain particulate samples during seven steady state modes of the 13-mode gaseous FTP. To perform all 13 modes was beyond the scope of work, yet to perform a composite 13-mode test would result in only a single value with no insight on the effect of speed and load. For most diesels, the emissions behavior can be estimated from a three point curve almost as well as from a five point curve. This was expected to be the case for particulates and sulfates since they were thought to be a function of fuel rate.

Accordingly, the particulate and sulfate testing followed the sequence of

| Mode | Speed | Load, Percent |
|---|---|---|
| 1 | Intermediate | 2 |
| 2 | Intermediate | 50 |
| 3 | Intermediate | 100 |
| 4 | Idle | --- |
| 5 | Rated | 100 |
| 6 | Rated | 50 |
| 7 | Rated | 2 |

This sequence resulted in four sample filters per mode, two 47 mm glass for particulate and two 47 mm Fluoropore for sulfate. A separate testing sequence was performed to obtain larger sample quantities for PNA analysis using the 8 x 10 high-vol system. Some additional discussion on calculation procedures is given in the results section.

## 6. Sulfate - $SO_2$ Analysis

The methods used to collect the samples of sulfate were discussed in the previous sub-section. This section will describe the utilization of the barium chloranilate analysis (BCA) method and its adaptation for use with diesel engines. The BCA method for sulfate and the SwRI-BCA method for $SO_2$ had been widely used with gasoline powered LDV's under EPA Contract 68-03-2118. Prior to this project, however, only limited, preliminary work had been performed by EPA at the Ann Arbor and Research Triangle Park labs with diesels. Although sulfate and $SO_2$ experiments were performed simultaneously, they will be described separately.

### a. Sulfate Method

The major concern in using the BCA method was the chemical work-up procedure for sulfate analysis once the filter had been collected. Although the soluble sulfates in the barium chloranilate isopropyl alcohol (IPA) solvent were analyzed using the same detection method for gasoline and diesel exhaust samples, a number of questions regarding sample extract were unanswered. One question was the ability of the existing extraction procedure to quantitatively extract the sulfate from the Fluoropore filter and the carbon particles. Replicate sulfate emissions tests were run using the Mercedes 240D to generate the exhaust samples. Sulfate samples were obtained using the dilution tunnel and sampling probe network for obtaining four simultaneous 47 mm Fluoropore filters. The filters were weighed before and after the test to validate equal particulate distribution on the filters.

Two of these four filters were ammoniated and extracted using the standard procedure as it is normally used for gasoline sulfates. The second two Fluoropore filters were ammoniated and extracted using partial immersion in an ultrasonic bath. All four filter extracts were filtered using Swinney syringe adapters with a 13 mm Fluoropore filter to remove the particulate. The results of this experiment indicated that there was essentially no difference between any of the four filters and that the two grossly different extraction procedures produced the same results.

The chief concern was that the collection of carbon particles on the filter provides a potentially ready-made absorber of hydrocarbons on the filter. Extraction of the hydrocarbons and the solubility of these in the IPA solvent could cause some potential interference problems. The group of greatest concern would be the substituted multiple ring aromatic hydrocarbons. Consequently, an experiment was designed to determine if this was a problem. Another SET was run and four more Fluoropore filters with equal weight distribution were obtained. The first two were ammoniated and extracted using the standard hydrocarbons. The cyclohexane was then removed and the filter and container were thoroughly dried. The IPA solvent was then added and extracted using the standard method. Again there was no difference between the cyclohexane washed and the unwashed filters for total sulfate content.

A similar experiment was conducted on a third SET where all four filters were ammoniated and extracted as usual. Two of the filters were run in the BCA system as usual and the final two were run without the barium chloranilate column in the system. The first two filters produced results equivalent to the two previous SET tests whereas the two samples analyzed without the BCA column had responses only slightly greater than the solvent blanks.

Based on the results using the Mercedes 240D exhaust sulfate samples, two previously assumed items have been verified. First, extraction of diesel sulfate samples can be effectively performed using the same "wrist-action" shake used for gasoline sulfate samples; and secondly, hydrocarbons in the sample were not found to produce any interferences. These same experiments were repeated on the DDAD 6V-71 HD engine and the same conclusion reached. The 2-stroke cycle engine produces a particulate with different composition from that of most four-stroke engines and was important to verification of the BCA system.

As a result of the above experiments, it was determined that the BCA method would be quite satisfactory for use with the range of diesel engines in this project. A description of the test procedure for sulfate determination is included in Appendix A.

### b. $SO_2$ Method

The measurement of $SO_2$ involved the evaluation of a TECO Model 10 pulsed fluorescense (PF) instrument as well as the SwRI-BCA method. Early in the project, the TECO Model 10 PF was tried with raw exhaust from a Cummins NTC-290 engine. The very brief try indicated apparently good response. This was prior to finding a number of problems with the TECO PF unit with gasoline exhaust and the subsequent development of the SwRI-BCA $SO_2$ method. A number of experiments were made to demonstrate the TECO PF unit with raw and tunnel diluted exhaust from the 6V-71 engine. The experiments with diluted exhaust were mostly promising but not considered applicable to the type of testing based on the 13-mode test.

About 2 ppm $SO_2$ was predicted in a nominal 12:1 diluted exhaust of the 6V-71 operating at full power, 2100 rpm, on 0.1 percent sulfur content fuel. Although this was measurable by the TECO, this would be the maximum value for 2100 rpm since in a normally aspirated, non-turbocharged diesel, the air flow is essentially constant while power is modulated by reducing the fuel rate. Therefore, at all lesser power settings, the $SO_2$ content in the exhaust would become substantially less, on the order of

5 to 1 for full load to no load at, say 2100 rpm. Idle will give even lower concentrations, making use of the dilution tunnel to give a suitable $SO_2$ sample of no practical interest.

This means the samples for $SO_2$ must be acquired from raw exhaust. Repeated tests with the TECO PF unit with raw exhaust were completely unsuccessful. The response was one of steady climbing meter deflection with time during an intentional steady state run. The instrument would span and zero properly before and after the test run, however. A sufficient number of tests were performed with the TECO to confirm this type of instrument response and to enable the conclusion to be made that only with some significant research and development effort will the TECO be made to work with diesel exhaust, at least our experience indicated this. Accordingly, the TECO experiments were discontinued since additional effort on the instrument just prolonged the start of sulfate test work which was a priority need.

As an alternate to the TECO, the SwRI-BCA wet collection system in hydrogen peroxide ($H_2O_2$) was used to collect $SO_2$. The exhaust first passed through a Fluoropore filter to remove sulfate. Then, the same system, developed by SwRI for use on gasoline $SO_2$ measurement on EPA Contract 68-03-2118, was used to prepare the sample for analysis by BCA method. This method is described in more detail in Appendix A.

### c. Sulfur Balance

In theory, the separate measurement of $SO_2$ and $SO_4^=$ concentrations in the exhaust can be multiplied by the exhaust flow rate, summed, and directly compared to the rate of sulfur into the engine which comes from the fuel. If the fuel sulfur content, fuel rate, and exhaust flow (intake air flow plus fuel rate) is accurately known, then a sulfur balance can be made for the engine.

From previous experience on a number of gasoline LDV's a sulfur balance of ± 10 percent has been achieved in most cases. This has been termed quite acceptable and was the target level of precision in this work with diesel cars and HD diesel engines. As a part of the preparations and pre-test calibrations, achievement of a satisfactory sulfur balance was one of the requirements for project validation. It turned out to be very involved and costly in terms of repeated operation and extensive sample analysis in the case of the DDAD 6V-71 engine.

In addition to this being the first HD engine thus evaluated, the engine required repeated attempts to demonstrate adequate sulfur recovery. One test series would result in generally lower than theoretical sulfur. The next test series would result in generally higher than it should. The patterns and trends in data defied explanation. Only after much patience and attention to detail was a sulfur balance demonstrated.

Work with the Cummins NTC-290, underway at the same time, resulted in a sulfur balance without undue difficulty. Such was the case with the light duty cars and the pick-up truck. There are some random instances where sulfur recoveries were outside the ± 10 percent; but in the majority of cases, adequate validation of the procedure was obtained.

### 7. Polynuclear Aromatic Matter - PNA

PNA compounds as a class and as individual contaminants were of interest in this project. Although there are several laboratory procedures available for their analysis, the major difficulty was analysis of PNA materials in diesel exhaust and of equal importance, the collection of a sample in a form suitable for such laboratory analysis. A substantial part of the coordination conference of September 17, 1974 with Dr. Somers, Dr. Bradow and Mr. Stahman, centered on the state-of-the-art of PNA measurement. At the outset of this project, the CRC APRAC CAPE-24-72 project with Gulf Research and Development was in progress.

The CAPE-24 project is concerned with sampling and analysis of PNA content of diesel and turbine engine exhaust. It was considered the most advanced PNA activity appropriate to diesels. It was intended that the SwRI-EPA work make use of the results in terms of a routine sampling and analysis technique. After telephone discussion with Dr. Rod Spindt, Project Leader at Gulf, it was obvious to the coordination conference attendees that the state of development was not considered reduced to routine. In essence, there are several adequate methods of PNA analysis of say, pure compounds, but no adequate sample collection and preparation scheme. There were unexplained losses during both these steps and the losses were sufficiently significant to warrant deferment of PNA analysis by the Gulf method.

Accordingly, and on the advice and consent of those present at the September 17th meeting, the measurement of BaP by the Eugene Sawicki thin layer chromatography method was to be employed. BaP is an elementary PNA and is generally found in diesel exhaust. It is considered to be a good indicator of the relative PNA content in that if it is high, PNA is probably high also. This is the same method then in use for Dr. Bradow on EPA Contract 68-02-0123 on diesel particulate. There were, at this time, still some unresolved questions regarding the sample collection and especially the preparation of the sample for analysis.

In support of Part VII and Contract 68-02-0123, a series of experiments were made to determine the ability of the thin layer analysis to measure known amounts of BaP deposited on a dirty diesel and a clean filter. Some experimentation was also performed to evaluate an alternate preparation method, using an ultrasonic bath with glass beads (per Dr. Bradow) instead of the standard soxhlet extraction.

The results of the above two sets of experiments confirmed that the thin layer method could measure BaP and served as a calibration of the technique. This calibration actually was found later to be misleading, as will be discussed shortly. The results of the other experiment to evaluate the ultrasonic and standard soxhlet extraction procedures showed that the standard soxhlet extraction of the Sawicki procedure gave satisfactory results. The alternative, ultrasonic method was not considered to be an overall improvement. In Appendix A is a copy of a letter to Dr. Rod Spindt from Dr. George Lee of Southwest Foundation for Research and Education. SFRE is a sister organization to SwRI and was responsible for BaP analysis. The letter outlines the BaP procedure used.

Of concern during the extensive BaP measurements made during Dr. Bradow's project (Contract 68-02-0123) and of concern at the coordinating conference, was the lack of agreement between thin layer BaP results from SFRE and that generally known from the literature.

As the volume of data increased, two facts were obvious: (a) trends in the data were reproducible, with reasonable precision, as a function of fuel, engine and load conditions and (b) the BaP values were significantly higher than corresponding values reported in the literature for benzo-a-pyrene. The data obtained in 68-02-0123 seemed generally an order of magnitude higher than other investigators although no other data by this specific method of sampling and analysis could be found for direct comparison.

In Contract 68-02-0123, PNA samples were obtained using tunnel air diluted exhaust and this was the first time such samples were acquired. Previous sampling methods involved cold traps, hot filtration, chemical absorption and other trapping methods for raw exhaust. The other concern was the sample transfer and preparation for analysis was introducing an artifact or some interference. The previously mentioned experiments were an attempt to validate the system and did not reveal any problem in the entire procedure and no specific reason for the higher than expected results. It was not until Dr. George Lee personally ran a series of analyses of the DDAD 8V-71TA and Perkins 6-247 engines that an error was discovered in the procedure as run at SFRE. These two engines were the last engines evaluated in the project.

The Sawicki analysis procedure (35) for determination of BaP involved a thin layer chromatographic separation, followed by fluorescence measurement. It was found that elution of the compounds on the thin layer plates was accomplished with a benzene:ether eluant rather than pentane:ether as suggested by Sawicki. The use of the benzene solvent afforded greater solubility and, therefore, less separation between similar compounds. In essence, a true separation was still being obtained since the spots used in the determinations were well below the solvent front. This combination of lower resolution, yet a constant retention factor, actually resulted in a reproducible measure of the polyorganic matter (POM) content of the particulate matter. This measure is the sum of several of the components in the system and not just a single compound as originally thought. The fluorescence response to the sample solution was obtained at the same excitation and emissions wavelengths that are used for BaP. Examples of the compounds which may be represented by this analysis are the isomers of dibenzanthracene, benzo-a-pyrene, benzo-e-pyrene, chrysene and possibly triphenylene and pyrene. As may be seen, this yields a broad representation of available materials.

Returning to the pentane:ether system showed the greater resolution of compounds as discussed by Sawicki. Analyses of the same or similar materials showed a marked reduction in fluorescence intensity from that found in the benzene system. Although it is still not possible to readily determine if interferences from other compounds are present, the values obtained more closely agree with values reported in the literature. The earlier calibration experiments failed to show this problem since the new and used filters were "spiked" with BaP. If several PNA's had been placed on the filter instead of BaP alone, the mistake in eluants would have been noticed.

The DDAD 8V-71TA and Perkins 6-247 samples were run with both solvents. BaP readings using the pentane:ether eluant were on the order of 7 to 39 percent of that obtained by the benzene:ether eluant. This brings the BaP reading much more in line with other published data and clarifies and explains the long standing concern over the apparently "high" BaP levels obtained earlier in this project and in Contract 68-02-0123.

In a sense, the use of the incorrect eluant by the technician, although highly regrettable, has resulted in values that may give more insight into the POM content than the BaP values alone. The readings are thus labeled benzene:ether soluble organic (B:ESO) matter expressed in terms of BaP, the compound used for calibration.

### 8. Elemental Analysis

The project plan originally called for elemental sulfur determination of the particulate using the 47 mm glass filter. The best known method for this analysis was the one used in EPA Contract 68-02-0123. A gravimetric method, ASTM D-1757, was employed by Galbraith Laboratories, a commercial testing lab located in Knoxville, Tennessee.

Determination of carbon, hydrogen, and nitrogen weight percentages in diesel particulate were also performed by Galbraith

Laboratories. Carbon and hydrogen were measured using ASTM method D-3178 and nitrogen was measured using ASTM D-3179. The results were corrected for blank filter content, which was reported to be very low.

Since performing the elemental sulfur measurements, additional work with Dr. Bradow on Contract 68-02-1777 has indicated X-ray fluorescence to be a more reliable method. The sulfur analyses in Part VII were by a state-of-the-art technique which apparently has since been superceded by the X-ray method. Future projects should be done by this more reliable method.

### 9. Vehicle Noise - LDV's only

This series of tests was intended to determine the maximum interior and exterior sound levels, in dBA scale, during idle and various driving modes. SAE J986a, Sound Level for Passenger Cars and Light Trucks, describes a test procedure that formed the basis for measurement and vehicle operation. A General Radio Type 1933 Precision Sound Level Analyzer, General Radio Type 1562-A Sound Level Calibrator, and General Radio Wind Screen, meeting the requirements of International Electrotechnical Commission Publication 179, were used.

#### a. Acceleration Drive-by

Exterior drive-by measurements were made at 15.24 m (50 feet) using the test procedure outlined in SAE J986a. Under this test, each vehicle approached a line 7.6 m(25 feet) before a line through the microphone normal to the vehicle path and acclerated, using the lowest transmission gear or range such that the front of the vehicle reached or passed a line 7.6 m(25 feet) beyond the microphone line when maximum rated engine speed was reached. The equipment used was a precision sound level meter, a sound level calibrator, and a calibrated wind screen. The test site was (as outlined in J986a) a flat open space, free of large reflecting surfaces (i.e., signs, hills, buildings) within 30.5 m (100 feet) of the test track.

Measurements were made (as outlined in J986a) 1.22 m (4 feet) above ground level and at 15.24 m (50 feet) from the centerline of the vehicle. This distance was considered adequate if the maximum noise level as measured on the "A-weighted" scale with a "fast" meter response was 10 dB above the ambient noise level. If this criterion could not be met, the measurements were made at 7.6 m (25 feet) by subtracting 6 dB from the measured values to extrapolate to an equivalent reading at 15.24 m (50 feet). If the level at 7.6 m (25 feet) was not 10 dB above ambient levels on a reasonably quiet day, this point was noted as well as the measured level and ambient level. The sound level for each side of the vehicle was the average of the two highest readings which were within 2 dB of each other. Tests were made with all windows fully closed and the vehicle accessories such as heater, air conditioner, or defroster (radio excluded) in operation at their highest apparent noise level.

Interior sound level determinations were the same as exterior except that the microphone was located 0.152 m (6 inches) to the right side of the driver's right ear. All other test procedures were as presented in J986a.

b. Constant Speed Drive-by

The exterior noise level with the vehicle passing by the microphone at a distance of 15.24 m (50 feet) was measured. The vehicle was in high gear and driven smoothly at 48.3 km/hr (30 mph) ± 5 percent. As in the acceleration test, the measurement was made at 7.6 m (25 feet) if "fast" meter response was not 10 dB above ambient noise level on the "A-weighted" scale. Six dB was subtracted from the measured values to extrapolate to an equivalent reading at 50 feet. Interior sound level determinations were made in the same manner as during the acceleration test. The sound level reported for this test was obtained in the manner outlined in the acceleration test already described.

c. Idle

This test included sound level measurements at 3.05 m (10 feet) distances from the front, rear, left (street side) and right (curb side) of the vehicle. The vehicle was parked and engine allowed to run at manufacturer's recommended low idle speed with transmission in neutral for at least one minute. Accessory items such as air conditioner or heater and defroster (radio excluded) operated at their highest apparent noise level. The sound level meter was positioned 3.05 m from each bumper mid-way between the sides of the car and 3.05 m from each side mid-way between the front and rear bumpers at 1.22 m (4 feet) height above the ground. The vehicle was then turned around and headed in the opposite direction and measurements repeated. Interior measurements were also obtained at the same single point used in drive-by tests.

Figure 9 contains six photographs taken during typical noise tests of the cars. The two top photos give some idea of the course and the type of terrain where measurements were taken. The upper left shows the Comprex-equipped Mercedes 220D and upper right photo is of the Mercedes 300D. The course was identical to that employed in

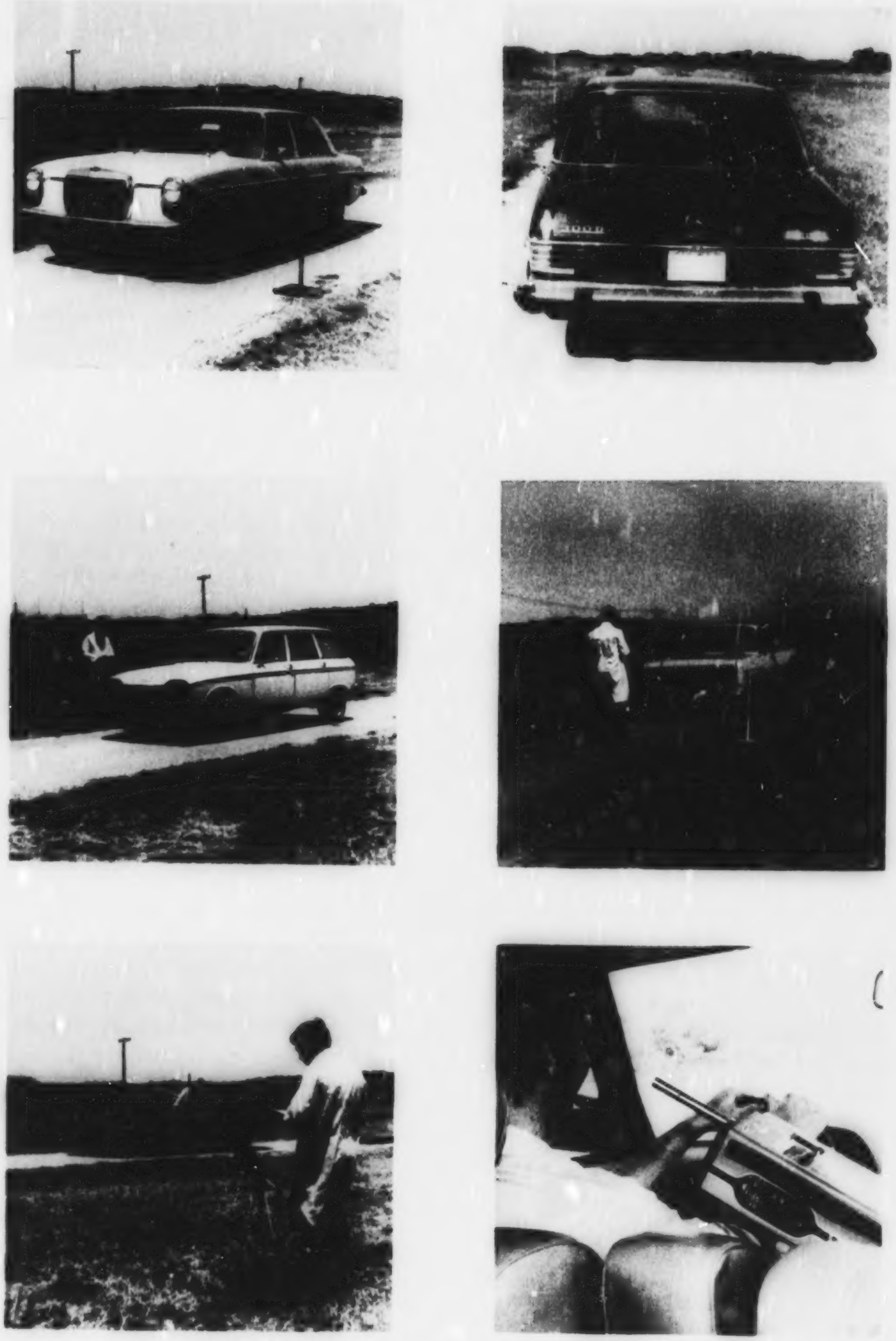


FIGURE 9. MEASUREMENT OF SOUND LEVEL FROM LIGHT DUTY DIESEL-POWERED VEHICLES

the earlier work and reported in References 12, 14 - 17. In fact, the test procedure described earlier in this subsection was identical to that developed and used in 1971.(12)

Figure 9 center photos also show typical locations around the car during the idle test. The center left photo is of the Peugeot 204D and the center right photo is of the Perkins 6-247 powered IHC pick-up truck. The General Radio Precision sound level instrument is shown in the two lower photos of Figure 9. The left photo shows the tripod-held meter at 15. 24 m (50 feet) from the test course as a test car, the Mercedes 240D, entered the "gate". The right photo shows the hand-held meter adjacent to the driver's right ear during the interior measurements.

## IV. RESULTS OF FIVE HD DIESEL ENGINES

This section summarizes the characterization emission data for the five HD diesel engine configurations tested. More complete data are included in the appendix.

### A. 13-Mode Gaseous Emission Results

Table 6 lists the results of replicate FTP gaseous emissions for all five configurations by the 13-mode method. Listed are the HC, CO, and $NO_x$ rates as well as cycle weighted BSFC, and maximum power at 2100 rpm. Table 7 lists the heavy duty diesel emission limits for comparison purposes with the Table 6 data. Note the 1977 California limits list an alternate standard with HC and $NO_2$ limits specified separately. The manufacturer may certify either way. The mixed metric, g/bhp-hr, units of expression are listed in parentheses and are those currently listed in Federal and California regulations. For purposes of discussion, the results will be described by engine make and model.

#### 1. DDAD 6V-71N

From Table 6, it is interesting to note the lower HC, CO and $NO_2$ when operating the engine with B60E injectors. It is likewise interesting to compare the average cycle weighted BSFC and max power at 2100 rpm. The B60E injectors resulted in poorer BSFC and lower power. Whether this is due to the injector design or to the retarded timing is unknown though the retarded timing is likely the major reason.

#### 2. Cummins NTC-290

Although the two Detroit Diesel engines were operated without difficulty, the Cummins NTC-290 had some minor but important items of repair necessary to obtain satisfactory emission results. This engine was installed on a similar dynamometer facility to the DDAD 6V-71 and early performance test at 2100 rpm, maximum power, indicated quite satifactory observed power of 220 kw (295 hp) and BSFC of 0.254 kg/kw-hr (0.417 lbs/bhp-hr).based on 55.7 kg/hr (122.8 lbs/hr) fuel rate.

The engine, at idle, emitted excessive amounts of blue smoke indicative of oil burning in the engine and exhaust system. The engine would eventually clear itself of blue smoke after prolonged high load operation only to "load-up" once again during idle. Several attempts were made to remedy this through engine operation, including a 14 hour run-in (the engine was well broken-in according to Cummins' Mr. Dennis Fox).

## TABLE 6. 13-MODE FTP GASEOUS EMISSIONS RESULTS FOR FIVE HD DIESEL ENGINE CONFIGURATIONS

| | | | Brake Specific Emissions g/kw-hr (g/hp-hr) | | | | Cycle BSFC kg/kw-hr | Power kw @ 2100 |
|---|---|---|---|---|---|---|---|---|
| Engine | Date | Run | HC | CO | $NO_2$ | $HC+NO_2$ | (lbs/hp-hr) | (hp @ 2100) |
| | | | LSN 60, 1.484 Timing | | | | | |
| DDAD 6V-71N | 3/19/75 | 1 | 2.967 | 7.723 | 17.171 | 20.138 | 0.287 | 140.9 |
| | 3/20/75 | 2 | 2.626 | 7.128 | 17.290 | 19.917 | 0.283 | 143.0 |
| | 3/20/75 | 3 | 2.710 | 7.657 | 17.095 | 19.805 | 0.282 | 143.0 |
| | Average | | 2.768<br>(1.997) | 7.502<br>(5.589) | 17.185<br>(12.803) | 19.953<br>(14.865) | 0.284<br>(0.467) | 142.3<br>(190.8) |
| | | | B60E Injectors, 1.500 Timing | | | | | |
| DDAD 6V-71N | 3/24/75 | 1 | 1.238 | 4.606 | 11.561 | 12.799 | 0.290 | 136.8 |
| | 3/24/75 | 2 | 1.357 | 4.686 | 12.008 | 13.365 | 0.288 | 136.8 |
| | Average | | 1.298<br>(0.967) | 4.646<br>(3.461) | 11.785<br>(8.780) | 13.082<br>(9.746) | 0.289<br>(0.475) | 136.8<br>(183.4) |
| | | | "Low" Emission Configuration | | | | | |
| Cummins NTC-290 | 5/14/75 | 1 | 0.899 | 2.600 | 6.638 | 7.537 | 0.289 | 216.1 |
| | 5/14/75 | 2 | 0.784 | 2.249 | 6.841 | 7.625 | 0.289 | 216.1 |
| | Average | | 0.842<br>(0.627) | 2.425<br>(1.807) | 6.740<br>(5.021) | 7.581<br>(5.648) | 0.289<br>(0.475) | 216.1<br>(289.7) |
| | | | "Current" Emission Configuration | | | | | |
| Cummins NTC-290 | 6/26/75 | 1 | 0.345 | 2.030 | 15.638 | 15.983 | 0.269 | 221.8 |
| | 6/26/75 | 2 | 0.412 | 1.946 | 14.542 | 14.944 | 0.272 | 221.3 |
| | Average | | 0.379<br>(0.282) | 1.988<br>(1.481) | 15.085<br>(11.238) | 15.464<br>(11.521) | 0.271<br>(0.445) | 221.6<br>(297.1) |
| | | | Standard Configuration | | | | | |
| DDAD 8V-71TA | 11/20/75 | 1 | 3.618 | 1.018 | 10.920 | 11.938 | 0.281 | 252.6 |
| | 11/20/75 | 2 | 3.683 | 0.898 | 10.800 | 11.698 | 0.283 | 252.6 |
| | Average | | 3.650<br>(2.719) | 0.958<br>(0.714) | 10.860<br>(8.091) | 11.841<br>(8.822) | 0.292<br>(0.480) | 252.6<br>(338.6) |

TABLE 7. HEAVY DUTY DIESEL (AND GASOLINE) EMISSION LIMITS

| | Units | CO | HC+NO$_2$ | |
|---|---|---|---|---|
| 1973 California and | g/kw-hr | 53.6 | 21.4 | |
| 1974 Federal | (g/bhp-hr) | (40) | (16) | |
| 1975 California | g/kw-hr | 40.2 | 13.4 | |
| | (g/bhp-hr) | (30) | (10) | |
| 1977 California | g/kw-hr | 33.5 | 6.7 | |
| | (g/bhp-hr) | (25) | (5) | |
| | | | HC | NO$_2$ |
| 1977 California | g/kw-hr | 33.5 | 1.3 | 10.1 |
| (alternate) | (g/bhp-hr) | (25) | (1) | (7.5) |

After a 20 minute idle, the exhaust pipe was disconnected from the turbocharger outlet. The wet oily condition in the turbocharger indicated that the turbocharger required resealing. With the consent of Mr. Dennis Fox, the turbocharger was removed and resealed by the local Cummins authorized sales and service dealer. On reassembly and additional check-out, extended engine operation, etc., the problem was found to persist though not to the degree earlier. The turbocharger did need resealing but apparently this was not the only source of oil.

Next, and with the consent of Mr. Fox, the injectors were removed and inspected. No. 2 injector had what appeared to be a damaged center o-ring and the No. 4 injector inlet screen had a large hole in the center. Several injector bottom and center o-rings had small nicks but nothing serious. Most upper o-rings had taken "a set" (had a flat spot) which is normal. The upper o-ring seals out oil, the center ring to upper ring seals the return fuel cavity and the lower to center ring seals the fuel supply. All o-rings were replaced and all injectors flowed by Cummins (local) to make certain they were satisfactory.

In its as-received originally run condition, the odor, smoke, and particulate levels were certainly not representative of this type engine. The odor was much stronger and irritating, especially to the eyes, than previous experience with similar engines indicates. The particulate filter would have certainly reflected the unburned and partially oxidized oil in the exhaust which is not representative of this engine. Likewise, smoke during idle and accel portions of the Federal test were not at all comparable to this engine's normal performance.

The repair and resealing of the turbocharger, injectors and the replacement of a faulty lead wire between the solenoid and fuel switch brought about acceptable engine performance with smoke and exhaust odor of the usual Cummins type. Listed in Table 6 are results of the replicate gaseous emissions tests taken with the engine in the "low" emission and in the "current" emission configuration. The "low" emission configuration involves operating the engine as-received from Cummins with fuel injection retarded in modes 3, 4, 5, 6, 8, 9, 10, and 11. These are basically the power producing modes of the 13-mode test. i.e., 25, 50, 75 and 100 percent of power at rated and at intermediate speeds.

The "current" emission level engine is for the engine adjusted to fixed fuel injection timing based on 1.4 mm (0.055 inch) injector lift at 5.16 mm (0.2032 inch) piston travel before TDC. The variable timing mechanism was locked in place by applying 620 kPa (90 psi) air to the air solenoid (with 12 volts continuously applied) to keep the engine in the advanced mode. The special fuel pump supplied with the experimental variable timing engine (low emission configuration) was replaced with a different pump, factory calibrated and tested for the "current" emission configuration.

After a number of trials, it was possible, with assistance of a local Cummins technician, to retime the engine and make the necessary adjustments to the engine to operate it in the "current" emissions configuration.

The Table 6 data indicates a substantial decrease in $NO_2$ when the variable timing "low" emission configuration was employed. $NO_2$ was just under half that of the current emission rate principally due to retard of fuel injection at all power producing modes of the 13-mode test sequence. The improvement in $NO_2$ was accompanied by a doubling in HC, some more CO (which is of negligible consequence) and a loss in BSFC from 0.271 to 0.289 kg of fuel per observed kw-hr.

Data furnished by Mr. Dennis Fox of Cummins on the "low" emission configuration, in a letter dated October 28, 1974, are as follows (converted to SI units):

| | |
|---|---|
| $NO_2$+HC | 6.24 g/kw-hr<br>(4.66 g/bhp-hr) |
| $NO_2$ | 5.44 g/kw-hr<br>(4.06 g/bhp-hr) |
| HC | 0.80 g/kw-hr<br>(0.60 g/bhp-hr) |

The engine was then, according to Mr. Fox, converted to the current configuration and power checked before returning the engine to its "low" emission configuration and shipped to Southwest Research Institute. In light of the changes made by Cummins before shipment and the problems regarding the turbocharger reseal and injector overhaul required before tests could be made, the level of agreement between Cummins and SwRI is acceptable.

SwRI has experienced much better agreement with Cummins with cross check engines in the past. However, a check of our modal results with Cummins data revealed slightly higher, but consistent modal NO readings at SwRI which accounts for the apparent difference in cycle composite $NO_2$ of about 1.3 g/kw-hr. Fuel rate, power, BSFC, and air rate, turbocharger pressure and rail pressure were all in good agreement between Cummins and SwRI for both configurations. No reason can be found for the difference except for the possibility of adjustments and maintenance given the engine between its initial test at Cummins and its test at SwRI some eight months later.

### 3. DDAD 8V-71TA

The replicate 13-mode HD gaseous emissions tests are summarized on Table 6. The averages shown may be compared to 0.899 g/kw-hr HC, 4.05 g/kw-hr CO, 12.246 g/kw-hr $NO_x$ and 13.145 g/kw-hr $NO_x$+HC obtained at the 1000 hr final durability test of this engine on 9/4/74. The lower $NO_x$ was apparently due to slightly lower air flow and lower $NO_x$ concentrations. In all, very good agreement between the two sets of data are evident.

For additional data, modal results, observed power, concentrations, etc., please refer to Appendix C of this report. Each run is summarized by a computer printout sheet containing pertinent raw, observed, and reduced data.

## B. Federal Smoke Results

Table 8 is a summary listing of the "a" acceleration, "b" lugdown and "c" peak opacity results of the Federal Smoke Test for HD diesel engines. Shown at the bottom of Table 8 are the Federal limits for new engine certification beginning in calendar year 1970 and then reduced in 1974 with addition of a peak limit.

Table 9 is a summary of the smoke and power observed during a separate test series to evaluate smoke behavior during maximum power curves run in 200 rpm increments. Each speed was held

## TABLE 8. FEDERAL SMOKE TEST RESULTS FOR FIVE HD DIESEL ENGINE CONFIGURATIONS

| | | | | Smoke Factor, % Opacity | | |
|---|---|---|---|---|---|---|
| Engine | Engine Configuration | Date | Run | a (accel) | b (lug) | c (peak) |
| DDAD 6V-71N | LSN 60 Injectors, 1.470 Timing | 2-18-75 | 1 | 5.3 | 1.8 | 15.1 |
| | | 2-18-75 | 2 | 5.6 | 2.0 | 14.9 |
| | | | Avg. | 5.5 | 1.9 | 15.0 |
| DDAD 6V-71N | B60E Injectors, 1.500 Timing | 8-25-75 | 1 | 12.3 | 5.6 | 26.4 |
| | | 8-25-75 | 2 | 12.2 | 5.7 | 24.8 |
| | | | Avg. | 12.3 | 5.7 | 25.6 |
| Cummins NTC-290 | "Low" Emission | 5-12-75 | 1 | 14.3 | 3.1 | 27.2 |
| | | 5-13-75 | 2 | 14.9 | 2.7 | 30.3 |
| | | | Avg. | 14.6 | 2.9 | 28.8 |
| Cummins NTC-290 | "Current" Emission | 6-25-75 | 1 | 14.5 | 2.8 | 24.5 |
| | | 6-25-75 | 2 | 14.4 | 2.5 | 24.7 |
| | | | Avg. | 14.5 | 2.7 | 24.6 |
| DDAD 8V-71TA | Standard | 10-29-75 | 1 | 14.0 | 6.5 | 25.7 |
| | | 10-29-75 | 2 | 13.8 | 6.8 | 23.3 |
| | | | Avg. | 13.9 | 6.7 | 24.5 |
| Federal HD Limits | | 1970 | | 40 | 20 | ---- |
| | | 1974 | | 20 | 15 | 50 |

## TABLE 9. SMOKE TEST RESULTS DURING MAXIMUM POWER TEST FOR FIVE HD DIESEL ENGINE CONFIGURATIONS

| Engine | Engine rpm | kw, obs | Opacity, % | kw, obs | Opacity, % |
|---|---|---|---|---|---|
| | | 60 LSN, 1.470 | | B60E, 1.500 | |
| DDAD 6V-71N | 2100 | 141.3 | 2.3 | 134.3 | 2.5 |
| | 1900 | 136.5 | 1.5 | 126.8 | 2.8 |
| | 1700 | 127.5 | 1.5 | 119.0 | 3.3 |
| | 1500 | 117.7 | 1.8 | 110.8 | 3.8 |
| | 1300 | 105.6 | 2.5 | 99.2 | 4.8 |
| | 1100 | 88.5 | 5.5 | 85.8 | 5.5 |
| | | "Low" Emission Conf. | | "Current" Emission Conf. | |
| Cummins NTC-290 | 2100 | 288.0 | 1.9 | 293.9 | 1.8 |
| | 1900 | 276.8 | 1.8 | 278.3 | 0.8 |
| | 1700 | 255.9 | 2.2 | 255.9 | 0.6 |
| | 1500 | 238.0 | 2.6 | 232.8 | 0.8 |
| | 1400 | 220.8 | 3.2 | 217.8 | 1.5 |
| | 1300 | 167.9 | 3.5 | 199.9 | 1.8 |
| | 1100 | 132.8 | 4.6 | 161.9 | 4.3 |
| | | Standard Configuration | | | |
| DDAD 8V-71TA | 2100 | 188.0 | 2.8 | | |
| | 1900 | 177.5 | 2.8 | | |
| | 1700 | 165.6 | 3.3 | | |
| | 1500 | 149.2 | 5.0 | | |
| | 1300 | 129.1 | 9.5 | | |
| | 1100 | 106.7 | 16.0 | | |

sufficiently long to enable true steady state performance to be obtained. Each engine model will be discussed separately.

### 1. DDAD 6V-71N

The basic bus engine was run with LSN 60 set to 1.470 and then with B60E injectors set to 1.500. The LSN injectors are of low sac needle design and the B60E are constant ending VCO (valve covers orifice) unit injectors. Both are of size 60 for essentially equivalent maximum power. The engine was run on a DF-1 kerosene type diesel doped to 0.1 percent sulfur by weight which is very similar to the national average fuel used by city buses. The a, b, and c smoke factors for this engine are shown in Table 8 for the duplicate runs made with each injector timing configuration.

Table 9 lists the power curve smoke data for this engine from 2100 to 1100 rpm. It may be noted from both Tables 8 and 9 that the smoke performance of this normally aspirated two-stroke cycle engine equipped with size 60 injectors and operating on kerosene fuel was quite satisfactory and typical of this type engine and configuration. The retarded timing and B60E injector design apparently was responsible for the lower observed power and increased smoke observed. The "a" and "b" factors were more than doubled when the B60E injectors were employed though still within the 20 percent "a" and 15 percent "b" smoke limits of 1974.

The timing retard was probably responsible for not only higher smoke but also lower power. The design of the injector itself may have also had some effect on smoke and power. The engine basically has an almost invisible exhaust as it should for city bus operation. The increase in smoke is certainly in the wrong direction for this application.

Recall from Table 6 the reduction in $NO_2$ from 17.2 to 11.8 g/kw-hr by ostensibly using the B60E injectors and timing retard. The B60E injector incorporates a constant ending of fuel injection regardless of power level and the VCO (valve covers orifice) tip assembly. The experimental VCO injectors evaluated some years earlier resulted in higher smoke than N or LSN style injectors quite likely due to the fewer and larger diameter openings.

### 2. Cummins NTC-290

The change in engine configuration from "low" to "current", though considered quite substantial, had little effect on smoke by the Federal Test Procedure. The results on Table 8 are consistent run-to-run and show no difference between configurations. Smoke from this engine is considered to be fairly low in light of four-stroke cycle turbocharged engines operating on DF-2 diesel fuel.

It may be noted from Table 9 that the smoke performance of this turbocharged four-stroke cycle engine in both "low" and "current" configuration was also essentially the same. The smoke performance during lug-down (b factor) was exceptionally low, below the limit of visibility. The power curve, a stepwise lug-down, confirms this observation.

The change in configurations appeared to have little effect on full power, maximum performance from the average power readings listed in Table 9 until the speed dropped below 1400 rpm. This is probably due primarily to the two different fuel pump calibrations employed in the "low" and "current" configurations. Smoke opacity readings of 4 percent and less represent an exceptionally clear exhaust since 3-4 percent opacity by the EPA smokemeter is generally the limit of visibility of diesel exhaust smoke.

### 3. DDAD 8V-71TA

Smoke results by the Federal HD test listed on Table 9 may be compared to a 9.1 percent "a", 3.9 percent "b" and 17 percent "c" value at the completion of the 1000 hour smoke-emissions durability test completed over one year before. The engine was partially disassembled for inspection between certification and these tests. The DF-2 test fuel was also slightly different from emissions DF-2 fuel normally used for smoke tests. Otherwise, no apparent reason is known for the increase in smoke.

During the power-smoke curve, reported on Table 9, the smoke was observed to be quite low between 2100 and 1500 rpm, the peak torque speed of the engine. At 1300 and especially 1100 rpm, engine speeds below peak torque speed, the smoke output increased substantially. This is typical and means that the truck driver must not "lug" or underspeed the engine in normal operation or smoke discharge level will be increased. For further detail regarding the Federal Smoke test results, please refer to Appendix D.

## C. Odor and Related Instrumental Analyses

The engine exhaust odor mapping and related instrumental analyses resulted in a substantial amount of data.

### 1. Odor Ratings by Trained Panel

Tables 10 and 11 summarize the average odor ratings and

## TABLE 10. AVERAGE ODOR PANEL RATINGS OF HD DIESEL ENGINES

100:1 Dilution

| Engine Condition | Odor Kit | DDAD 6V-71 | | Cummins NTC-290 | | DDAD 8V-71TA |
|---|---|---|---|---|---|---|
| | | LSN 60 | B 60 E | "Current" | "Low" | |
| Intermediate Speed, 2% load | D | 2.9 | 3.1 | 2.4 | 2.4 | 2.8 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | O | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 |
| | A | 0.7 | 0.8 | 0.5 | 0.5 | 0.6 |
| | P | 0.5 | 0.6 | 0.3 | 0.4 | 0.6 |
| | Total | 6.1 | 6.5 | 5.1 | 5.2 | 5.9 |
| Intermediate Speed, 50% load | D | 2.5 | 2.3 | 2.3 | 2.6 | 2.5 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | O | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| | A | 0.6 | 0.5 | 0.5 | 0.6 | 0.6 |
| | P | 0.4 | 0.4 | 0.3 | 0.4 | 0.4 |
| | Total | 5.4 | 5.1 | 5.0 | 5.5 | 5.4 |
| Intermediate Speed, 100% load | D | 4.7 | 3.4 | 2.0 | 2.3 | 2.8 |
| | B | 1.6 | 1.0 | 1.0 | 1.0 | 1.0 |
| | O | 1.0 | 1.0 | 0.9 | 0.8 | 1.0 |
| | A | 0.9 | 0.7 | 0.3 | 0.6 | 0.7 |
| | P | 1.2 | 0.9 | 0.3 | 0.3 | 0.5 |
| | Total | 9.4 | 7.0 | 4.5 | 5.0 | 6.0 |
| High Speed, 2% load | D | 2.9 | 3.4 | 2.3 | 2.2 | 2.6 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | O | 0.9 | 1.0 | 0.7 | 0.8 | 0.9 |
| | A | 0.8 | 0.8 | 0.5 | 0.4 | 0.6 |
| | P | 0.5 | 0.7 | 0.3 | 0.3 | 0.5 |
| | Total | 6.1 | 6.9 | 4.8 | 4.7 | 5.6 |
| High Speed, 50% load | D | 2.7 | 2.5 | 2.5 | 3.0 | 2.5 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |
| | O | 1.0 | 1.0 | 0.9 | 1.0 | 0.9 |
| | A | 0.6 | 0.5 | 0.5 | 0.7 | 0.7 |
| | P | 0.5 | 0.5 | 0.3 | 0.5 | 0.3 |
| | Total | 5.8 | 5.5 | 5.2 | 6.2 | 5.3 |
| High Speed, 100% load | D | 4.1 | 3.7 | 3.0 | 2.1 | 2.7 |
| | B | 1.2 | 1.1 | 1.0 | 1.0 | 1.0 |
| | O | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 |
| | A | 1.0 | 0.8 | 0.6 | 0.5 | 0.6 |
| | P | 0.9 | 0.9 | 0.6 | 0.2 | 0.5 |
| | Total | 8.2 | 7.5 | 6.2 | 4.7 | 5.7 |

## TABLE 10. (Cont'd) AVERAGE ODOR PANEL RATINGS OF HD DIESEL ENGINES

| Engine Condition | Odor Kit | DDAD 6V-71 | | Cummins NTC-290 | | DDAD 8V-71TA |
|---|---|---|---|---|---|---|
| | | LSN 60 | B 60 E | "Current" | "Low" | |
| Idle Speed, no load | D | 3.0 | 2.8 | 2.5 | 3.3 | 2.8 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | O | 0.9 | 0.9 | 0.9 | 1.0 | 0.9 |
| | A | 0.8 | 0.6 | 0.5 | 0.7 | 0.7 |
| | P | 0.6 | 0.5 | 0.4 | 0.8 | 0.4 |
| | Total | 6.3 | 5.8 | 5.3 | 6.8 | 5.8 |
| **Transient Results** | | | | | | |
| Idle Acceleration | D | 5.1 | 3.8 | 3.6 | 3.5 | 3.8 |
| | B | 1.8 | 1.2 | 1.1 | 1.0 | 1.1 |
| | O | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 |
| | A | 1.0 | 0.9 | 0.8 | 0.7 | 0.9 |
| | P | 1.1 | 1.0 | 0.9 | 0.8 | 0.8 |
| | Total | 10.1 | 8.0 | 7.4 | 7.0 | 7.6 |
| Acceleration | D | 4.6 | 3.6 | 3.0 | 2.9 | 3.0 |
| | B | 1.5 | 1.1 | 1.0 | 1.0 | 1.1 |
| | O | 1.1 | 1.0 | 1.0 | 0.9 | 0.9 |
| | A | 1.0 | 0.8 | 0.6 | 0.8 | 0.7 |
| | P | 1.0 | 1.0 | 0.5 | 0.6 | 0.6 |
| | Total | 9.2 | 7.5 | 6.1 | 6.2 | 6.3 |
| Deceleration | D | 3.2 | 2.9 | 5.2 | 4.3 | 2.9 |
| | B | 1.0 | 1.0 | 1.8 | 1.4 | 1.0 |
| | O | 1.0 | 0.9 | 1.2 | 1.0 | 1.0 |
| | A | 0.9 | 0.7 | 1.0 | 1.0 | 0.7 |
| | P | 0.7 | 0.5 | 1.2 | 1.1 | 0.6 |
| | Total | 6.8 | 6.0 | 10.4 | 8.8 | 6.2 |

### TABLE 11. AVERAGE OF EXHAUST ANALYSES TAKEN SIMULTANEOUSLY WITH ODOR RATINGS OF HD ENGINES DURING STEADY-STATE CONDITIONS

| Engine Condition | Exhaust Emission | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|---|
| | | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| Intermediate Speed, 2% load | HC, ppm C | 175 | 121 | 78 | 96 | 101 |
| | CO, ppm | 145 | 199 | 110 | 139 | 123 |
| | NO-NDIR, ppm | 160 | 72 | 164 | 115 | 118 |
| | NO-CL, ppm | 141 | 68 | 155 | 101 | 108 |
| | $NO_x$-CL, ppm | 178 | 92 | 181 | 114 | 135 |
| | $CO_2$, % | 1.2 | 1.1 | 2.2 | 2.1 | 1.6 |
| | TIA | 1.1 | 1.4 | 1.4 | 1.3 | 1.8 |
| | LCA, µg/l | 19.8 | 18.4 | 7.7 | 6.4 | 9.4 |
| | LCO, µg/l | 1.2 | 2.4 | 2.2 | 2.1 | 5.2 |
| Intermediate Speed, 50% load | HC, ppm C | 235 | 77 | 64 | 93 | 89 |
| | CO, ppm | 98 | 86 | 144 | 176 | 93 |
| | NO-NDIR, ppm | 713 | 405 | 887 | 314 | 527 |
| | NO-CL, ppm | 652 | 377 | 844 | 288 | 511 |
| | $NO_x$-CL, ppm | 743 | 409 | 898 | 294 | 535 |
| | $CO_2$, % | 3.3 | 3.3 | 6.2 | 6.3 | 4.3 |
| | TIA | 1.0 | 1.1 | 1.2 | 1.4 | 1.7 |
| | LCA, µg/l | 23.7 | 10.7 | 4.5 | 8.6 | 9.9 |
| | LCO, µg/l | 1.1 | 1.3 | 1.9 | 2.4 | 4.4 |
| Intermediate Speed, 100% load | HC, ppm | 439 | 208 | 71 | 86 | 100 |
| | CO, ppm | 7842 | 3518 | 619 | 509 | 1132 |
| | NO, NDIR, ppm | 809 | 1042 | 2069 | 717 | 1093 |
| | NO-CL, ppm | 752 | 960 | 2032 | 678 | 1020 |
| | $NO_x$-CL, ppm | 789 | 994 | 2157 | 694 | 1045 |
| | $CO_2$, % | 6.2 | 6.2 | 9.6 | 9.1 | 6.4 |
| | TIA | 1.5 | 1.4 | 1.3 | 1.3 | 1.8 |
| | LCA, µg/l | 55.1 | 25.8 | 4.3 | 4.9 | 8.9 |
| | LCO, µg/l | 3.1 | 2.5 | 2.3 | 2.4 | 5.8 |
| High Speed, 2% load | HC, ppm | 199 | 130 | 72 | 90 | 92 |
| | CO, ppm | 117 | 225 | 103 | 114 | 84 |
| | NO-NDIR, ppm | 183 | 74 | 221 | 140 | 122 |
| | NO-CL, ppm | 159 | 69 | 195 | 126 | 123 |
| | $NO_x$-CL, ppm | 194 | 95 | 218 | 139 | 149 |
| | $CO_2$, % | 1.5 | 1.5 | 2.8 | 2.8 | 2.1 |
| | TIA | 1.1 | 1.4 | 1.3 | 1.4 | 1.7 |
| | LCA, µg/l | 23.2 | 19.4 | 5.4 | 10.2 | 11.4 |
| | LCO, µg/l | 1.3 | 2.6 | 2.0 | 2.5 | 5.4 |

### TABLE 11. (Cont'd) AVERAGE OF EXHAUST ANALYSES TAKEN SIMULTANEOUSLY WITH ODOR RATINGS OF HD ENGINES DURING STEADY-STATE CONDITIONS

| Engine Condition | Exhaust Emission | DDAD 6V-71 LSN 60 | DDAD 6V-71 B 60 E | Cummins NTC-290 "Current" | Cummins NTC-290 "Low" | DDAD 8V-71TA |
|---|---|---|---|---|---|---|
| High Speed, 50% load | HC, ppm | 259 | 92 | 64 | 95 | 111 |
| | CO, ppm | 95 | 80 | 92 | 123 | 76 |
| | NO-NDIR, ppm | 627 | 315 | 714 | 255 | 413 |
| | NO-CL, ppm | 580 | 285 | 653 | 228 | 394 |
| | $NO_x$-CL, ppm | 629 | 314 | 689 | 241 | 437 |
| | $CO_2$, % | 95 | 3.4 | 5.4 | 5.3 | 3.9 |
| | TIA | 1.1 | 1.2 | 1.4 | 1.4 | 1.7 |
| | LCA, µg/l | 25.7 | 13.0 | 4.1 | 8.7 | 11.4 |
| | LCO, µg/l | 1.3 | 1.6 | 2.4 | 2.6 | 5.0 |
| High Speed, 100% load | HC, ppm | 333 | 143 | 83 | 88 | 85 |
| | CO, ppm | 1770 | 1267 | 108 | 145 | 88 |
| | NO-NDIR, ppm | 1136 | 868 | 1851 | 669 | 1010 |
| | NO-CL, ppm | 1057 | 823 | 1783 | 601 | 944 |
| | $NO_x$-CL, ppm | 1111 | 859 | 1907 | 616 | 988 |
| | $CO_2$, % | 6.2 | 6.2 | 6.6 | 7.0 | 5.4 |
| | TIA | 1.5 | 1.5 | 1.4 | 1.6 | 1.8 |
| | LCA, µg/l | 48.9 | 24.5 | 5.0 | 6.8 | 10.0 |
| | LCO, µg/l | 3.0 | 3.0 | 2.5 | 3.9 | 5.5 |
| Idle Speed, 2% load | HC, ppm | 176 | 146 | 99 | 137 | 141 |
| | CO, ppm | 126 | 132 | 91 | 126 | 87 |
| | NO-NDIR, ppm | 183 | 100 | 133 | 89 | 180 |
| | NO-CL, ppm | 160 | 95 | 111 | 78 | 176 |
| | $NO_x$-CO, ppm | 199 | 117 | 142 | 93 | 196 |
| | $CO_2$, % | 1.0 | 0.9 | 1.5 | 1.5 | 1.1 |
| | TIA | 1.0 | 1.2 | 1.3 | 1.4 | 1.7 |
| | LCA, µg/l | 17.9 | 17.1 | 5.6 | 10.7 | 8.9 |
| | LCO, µg/l | 1.0 | 1.6 | 2.2 | 2.9 | 5.0 |

emissions measured at the same time. Table 12 lists pertinent engine data for the five engine configurations. Each engine model is discussed separately.

### a. DDAD 6V-71N

Table 10 lists the average odor panel ratings for both types of injector-timing configurations. Looking mainly at the "D" composite rating, it seems that the B60E had lower "D" ratings at high power and higher "D" ratings at no load than the LSN 60 injectors. Other steady states and idle seemed little affected. The B60E injectors were apparently responsible for lower idle-accel, accel and slightly less deceleration odor.

The action of the B60E configuration on lower exhaust odor intensities is somewhat a surprise, especially in light of runs several years ago with a set of experimental VCO injectors in a city bus. The fuel and operating conditions were essentially the same though the injectors were definitely different. Possibly the constant ending of injection is responsible. This design feature would have effect only at part load because at full load the start of injection would be equivalent to the start of injection with the LSN-60 injectors given the same basic engine timing. The VCO injectors run before resulted in noticeably higher odor than the usual N or LSN injectors.

The steady state operating conditions used for odor measurement of the 6V-71 engine were no, half and full load at 900 and 1500 rpm. These speeds are consistent with most city buses equipped with 2 speed transmission. Also, this is the first time odor measurements have been attempted using a stationary dynamometer operated engine in place of the usual chassis dynamometer operated full size city bus. The bus operating conditions, including transients, were as closely replicated as possible using previous experience in bus engine operation and a large inertia wheel for simulation of acceleration and deceleration type operation.

Table 11 lists most of the gaseous emissions taken simultaneously with odor measurements. Also listed in Table 12 are fuel flow and air flow rates. These are averages of two days replicate operation, each day the average of three replicate, random ordered, steady states. As with odor ratings, the gaseous emissions, Table 11, were quite repeatable from day to day. The oxides of nitrogen measurement NO and $NO_x$ were lower for the B60E injectors and retarded timing combination. One exception was 900 rpm and full load during which both CL and NDIR indicated more NO and $NO_x$ with the B60E injectors.

### b. Cummins NTC-290

## TABLE 12. AVERAGE ENGINE OPERATING DATA TAKEN SIMULTANEOUSLY WITH ODOR RATINGS OF HD ENGINES DURING STEADY-STATE CONDITIONS

| Engine Condition | Engine Parameter | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|---|
| | | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| Intermediate Speed 2% Load | Engine Speed, rpm | 900 | 900 | 1400 | 1400 | 1400 |
| | Power Output, obs kw | 1.4 | 1.5 | 3.4 | 3.3 | 3.5 |
| | Fuel Rate, kg/hr | 3.2 | 2.9 | 5.7 | 5.5 | 6.2 |
| | Air Rate, kg/min | 10.3 | 10.5 | 10.3 | 10.4 | 17.5 |
| | BSFC kg/kw-hr | 2.285 | 1.933 | 1.676 | 1.666 | 1.666 |
| | Inlet Temp, °C | 24.4 | 26.1 | 25.6 | 27.2 | 24.8 |
| | Exhaust Temp, °C | 113.3 | 113.3 | 196.7 | 202.8 | 150.9 |
| | Inlet Rest., mm $H_2O$ | 190.5 | 198.1 | 96.5 | 124.5 | 181.4 |
| | Exh. Rest., mm Hg | 3.8 | 3.6 | 3.0 | 3.3 | 7.3 |
| Intermediate Speed 50% Load | Engine Speed, rpm | 900 | 900 | 1400 | 1400 | 1400 |
| | Power Output, obs kw | 36.0 | 36.5 | 84.2 | 81.8 | 93.1 |
| | Fuel Rate, kg/hr | 8.9 | 8.7 | 20.2 | 21.2 | 23.9 |
| | Air Rate, kg/min | 10.5 | 10.1 | 11.7 | 12.2 | 20.3 |
| | BSFC, kg/kw-hr | 0.247 | 0.238 | 0.239 | 0.259 | 0.256 |
| | Inlet Temp, °C | 25.0 | 26.7 | 24.4 | 27.2 | 25.2 |
| | Exhaust Temp, °C | 218.3 | 220.6 | 360.0 | 395.0 | 277.4 |
| | Inlet Rest., mm $H_2O$ | 188.0 | 203.2 | 129.5 | 167.6 | 226.6 |
| | Exh. Rest., mm Hg | 5.3 | 5.1 | 5.1 | 5.6 | 12.1 |
| Intermediate Speed 100% | Engine Speed, rpm | 900 | 900 | 1400 | 1400 | 1400 |
| | Power Output, obs kw | 71.8 | 73.0 | 168.5 | 163.3 | 186.2 |
| | Fuel Rate, kg/hr | 19.4 | 17.6 | 38.3 | 39.2 | 47.9 |
| | Air Rate, kg/min | 10.6 | 10.3 | 14.8 | 15.9 | 25.3 |
| | BSFC, kg/kw-hr | 0.270 | 0.241 | 0.227 | 0.240 | 0.257 |
| | Inlet Temp, °C | 24.4 | 27.7 | 25.0 | 26.7 | 25.6 |
| | Exhaust Temp, °C | 410.0 | 395.6 | 513.3 | 521.1 | 405.7 |
| | Inlet Rest., mm $H_2O$ | 190.5 | 203.2 | 205.7 | 241.3 | 325.4 |
| | Exh. Rest., mm Hg | 5.3 | 6.6 | 9.1 | 9.4 | 24.5 |
| High Speed 2% Load | Engine Speed, rpm | 1500 | 1500 | 2100 | 2100 | 2100 |
| | Power Output, obs, kw | 2.3 | 2.3 | 4.5 | 2.2 | 4.7 |
| | Fuel Rate, kg/hr | 6.1 | 5.9 | 12.6 | 12.5 | 12.9 |
| | Air Rate, kg/min | 16.8 | 16.5 | 16.9 | 16.6 | 26.8 |
| | BSFC, kg/kw-hr | 2.652 | 2.565 | 2.80 | 5.681 | 2.744 |
| | Inlet Temp., °C | 24.4 | 26.1 | 24.4 | 27.8 | 25.3 |
| | Exhaust Temp., °C | 148.3 | 153.9 | 241.1 | 255.0 | 172.7 |
| | Inlet Rest., mm $H_2O$ | 391.2 | 419.1 | 243.8 | 264.2 | 371.9 |
| | Exh. Rest., mm Hg | 9.9 | 9.7 | 7.6 | 7.6 | 19.9 |

### TABLE 12. (Cont'd) AVERAGE ENGINE OPERATING DATA TAKEN SIMULTANEOUSLY WITH ODOR RATINGS OF HD ENGINES DURING STEADY-STATE CONDITIONS

| Engine Condition | Engine Parameter | DDAD 6V-71 |  | Cummins NTC-290 |  | DDAD |
|---|---|---|---|---|---|---|
|  |  | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| High Speed, 50 % Load | Engine Speed, rpm | 1500 | 1500 | 2100 | 2100 | 2100 |
|  | Power Output, obs kw | 57.8 | 56.7 | 111.8 | 107.6 | 126.3 |
|  | Fuel Rate, kg/hr | 14.8 | 14.0 | 30.2 | 33.7 | 35.5 |
|  | Air Rate, kg/min | 16.8 | 16.4 | 20.9 | 23.3 | 30.8 |
|  | BSFC, kg/kw-hr | 0.256 | 0.246 | 0.270 | 0.313 | 0.281 |
|  | Inlet Temp., °C | 24.4 | 27.2 | 25.6 | 26.1 | 25.2 |
|  | Exhaust Temp., °C | 258.8 | 261.1 | 366.7 | 392.8 | 259.4 |
|  | Inlet Rest., mm $H_2O$ | 393.7 | 424.2 | 363.2 | 442.0 | 468.5 |
|  | Exh. Rest., mm Hg | 12.4 | 12.2 | 12.7 | 17.0 | 31.3 |
| High Speed, 100% Load | Engine Speed, rpm | 1500 | 1500 | 2100 | 2100 | 2100 |
|  | Power Output, obs kw | 115.6 | 112.6 | 223.0 | 214.1 | 252.6 |
|  | Fuel Rate, kg/hr | 27.7 | 26.3 | 51.8 | 55.0 | 61.7 |
|  | Air Rate, kg/min | 16.7 | 16.6 | 27.2 | 28.7 | 36.2 |
|  | BSFC, kg/kw hr | 0.239 | 0.233 | 0.232 | 0.257 | 0.244 |
|  | Inlet Temp., °C | 24.4 | 25.6 | 24.4 | 26.7 | 25.4 |
|  | Exhaust Temp., °C | 440.0 | 430.6 | 458.3 | 488.3 | 349.5 |
|  | Inlet Rest., mm $H_2O$ | 391.2 | 414.0 | 591.8 | 637.5 | 634.4 |
|  | Exh. Rest., mm Hg | 18.0 | 17.0 | 12.7 | 27.9 | 52.1 |
| Idle | Engine Speed, rpm | 430 | 430 | 615 | 615 | 480 |
|  | Power Output, obs kw | 0 | 0 | 0 | 0 | 0 |
|  | Fuel Rate, kg/hr | 1.2 | 1.2 | 1.4 | 1.4 | 1.5 |
|  | Air Rate, kg/min | 4.8 | 4.7 | 4.8 | 4.2 | 6.2 |
|  | Inlet Temp., °C | 24.4 | 27.2 | 25.0 | 27.8 | 24.6 |
|  | Exhaust Temp, °C | 108.3 | 110.6 | 158.9 | 168.3 | 134.6 |
|  | Inlet Rest., mm $H_2O$ | 63.5 | 66.0 | 12.7 | 25.4 | 39.5 |
|  | Exh. Rest., mm Hg | 0 | 0 | 0 | 0 | 0 |

Table 10 also lists the average odor panel ratings for both the "Current" and "Low" emission configuration NTC-290 engine. The retarded timing operates on the "Low" configuration during the half and fully loaded operation. "D" odor ratings were slightly higher at half and full load at intermediate, 1400 rpm, speed and at 2100 (high) rpm half load. The reverse was true for the retarded "Low" configuration at full load, 2100 rpm in that "D" was lower with the "Low" or retarded system. Idle was a condition that produced higher "D" intensity with the "Low" configuration.

Little difference in odor was found during transients except deceleration in which the low configuration apparently resulted in a lower average "D" rating. The reasons for the overall inconsistent effect of the engine emission configuration on odor is not understood. What was somewhat of concern was the odor intensities, regardless of configuration, found during transients, especially the deceleration. Like the 6V-71, this is the first time odor tests have been made with stationary operated engines during transient operation at SwRI.

The use of a large inertia wheel does permit very repeatable and road-like operation of the engine. The deceleration mode is one that is quite time dependent. The time following closed throttle deceleration was carefully investigated to make sure a representative maximum odor occurrence would be presented to the panel for rating.

Table 11 also lists exhaust emissions data for the Cummins NTC-290 engine. The engine speeds used were 2100 and 1400 rpm, same as the 13-mode FTP test speeds. HC and CO were slightly, but consistently, higher with the "Low" configuration. One exception was CO at 1400 rpm (intermediate speed) full load. Oxides of nitrogen were consistently and grossly lower as expected during half and full load regardless of speed. Exactly why $NO_x$ was also lower at idle and the two no load conditions is unknown.

c. DDAD 8V-71TA

Also listed on Tables 10, 11, and 12 are the average odor, gaseous emissions and operating data, respectively. This turbocharged and roots blown truck engine, operated on DF-2 fuel, had, under some conditions, lower odor ratings than the 6V-71 DDAD engine operating on DF-1 fuel. This was noticeable during the intermediate and high speed 100 percent load points, and both acceleration conditions.

For additional details and supporting data for Tables 10 and 11, please refer to Appendices E and F. Appendix E contains the average panel ratings for each run (triplicate runs in random order for steady states and quadruplicate runs in random order for the three transients). For the DDAD 6V-71 and Cummins NTC-290, the data is grouped in sets of five tables each. The first table is a summary comparison between the two configurations with daily average results tabulated. The other four tables of the set list the run by run results for each day of testing, two days for each configuration.

The 8V-71TA engine was only run in one configuration, standard, and three odor panel test days were made. The Appendix F instrumental data on emissions are presented similarly to the odor data in Appendix E.

### d. Analysis of Panel Ratings

Figures 10, 11 and 12 are plots of the odor data listed in Table 10. The top set of graphs are for the "D" diesel intensity ratings at various steady states and are plotted against percent power. The lower graph summarizes the composite "D"+"B"+"O"+"A"+"P" for all ten conditions. The transients more often gave highest ratings. From Figure 10, the B60E injectors produced lower odor under some conditions. The two emission configurations used with the Cummins engine, Figure 11, produced inconsistent odor differences.

Neither engine speed or power setting had a noticeable effect on odor for the 8V-71 engine, Figure 12. The ratings were rather constant and consistent. The lower graph of Figure 12 shows that idle-accel was the only condition which could be considered different from the others. Otherwise, the odor levels must be termed about the same. With "D" levels on the order of 2.5 to 3, the odor from this turbocharged two-stroke cycle engine must also be termed light to moderate in odor strength. This is the first opportunity for an evaluation of odor to be made from this type engine under the long range investigation. The relatively low odor levels, at 100:1 dilution, are encouraging.

Finally, the shapes of the "D" odor intensity for the two DDAD engines was mainly one of lowest odor at the mid-power point, although the differences due to power or speed were, for the most part, rather minimal.

### 2. Odor Ratings by DOAS Instrument

Listed on Table 11 are the three odor rating values, TIA, LCO and LCA, for each of the seven steady state conditions. The TIA is based on the measurement of LCO and is the value used to predict the total intensity of aroma. For the run-by-run data on which the averages are based, please refer to Appendix F.

Figures 13 and 14 contain graphs relating TIA to operating point

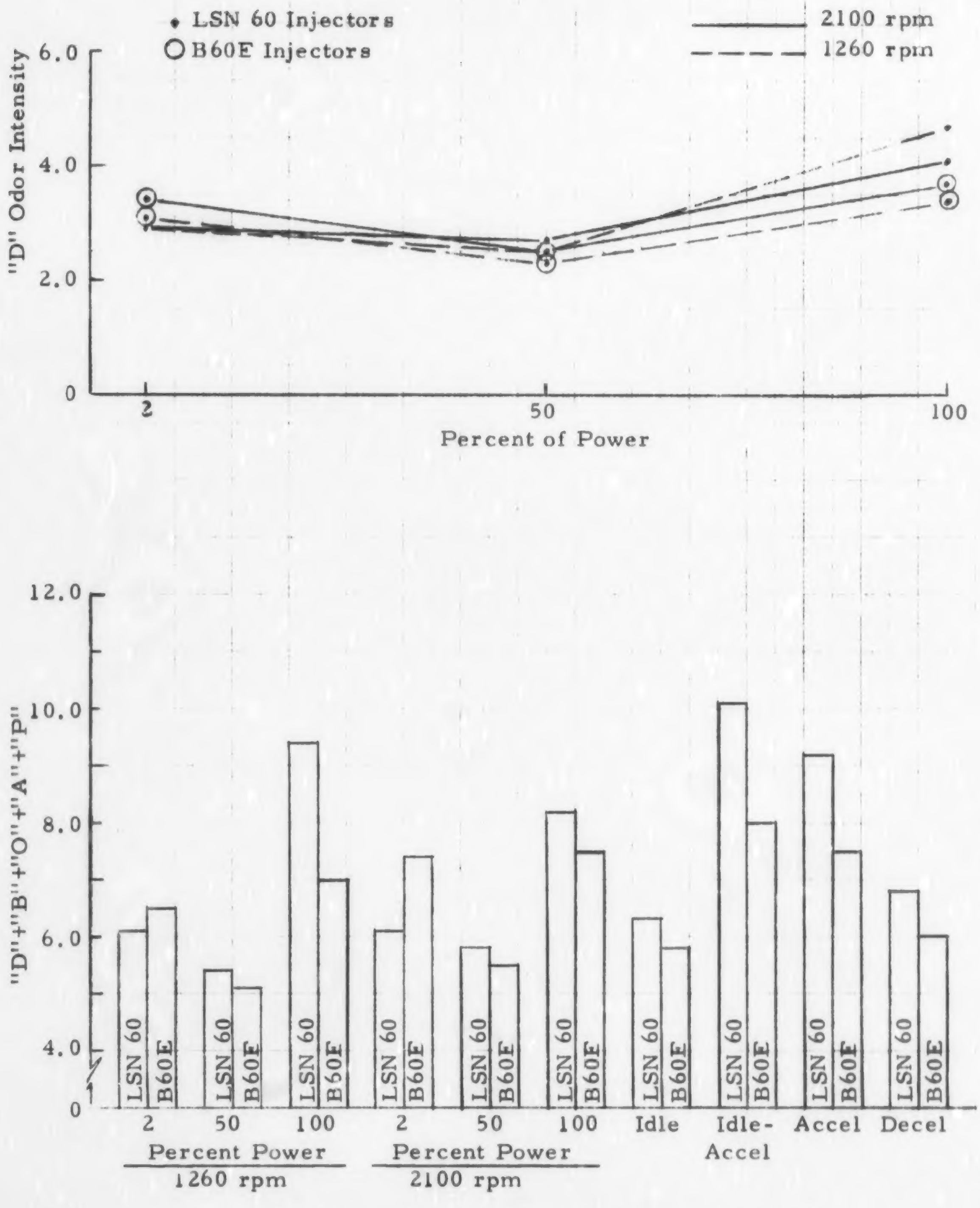
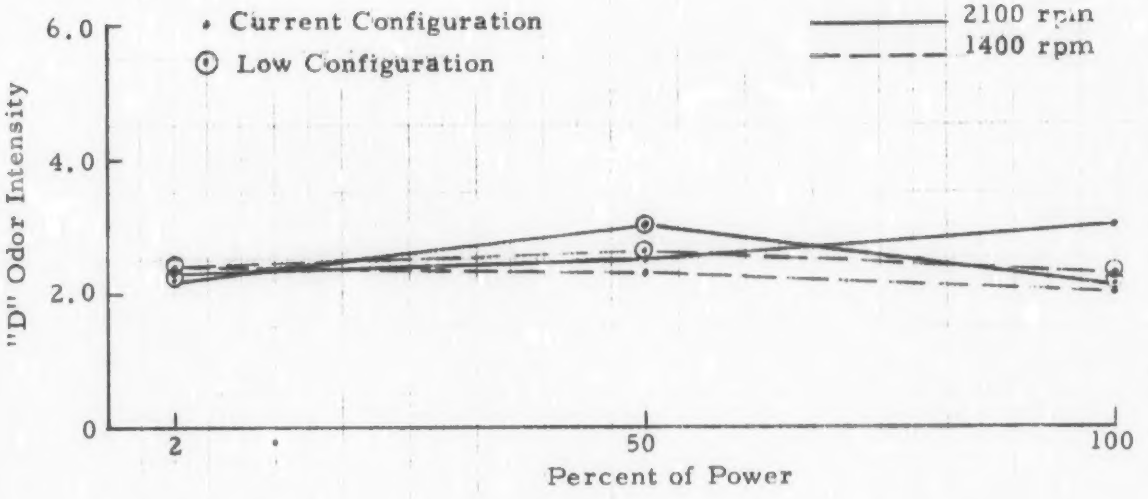


FIGURE 10. DETROIT DIESEL 6V-71 ENGINE DIESEL ODOR INTENSITY BY TRAINED PANEL



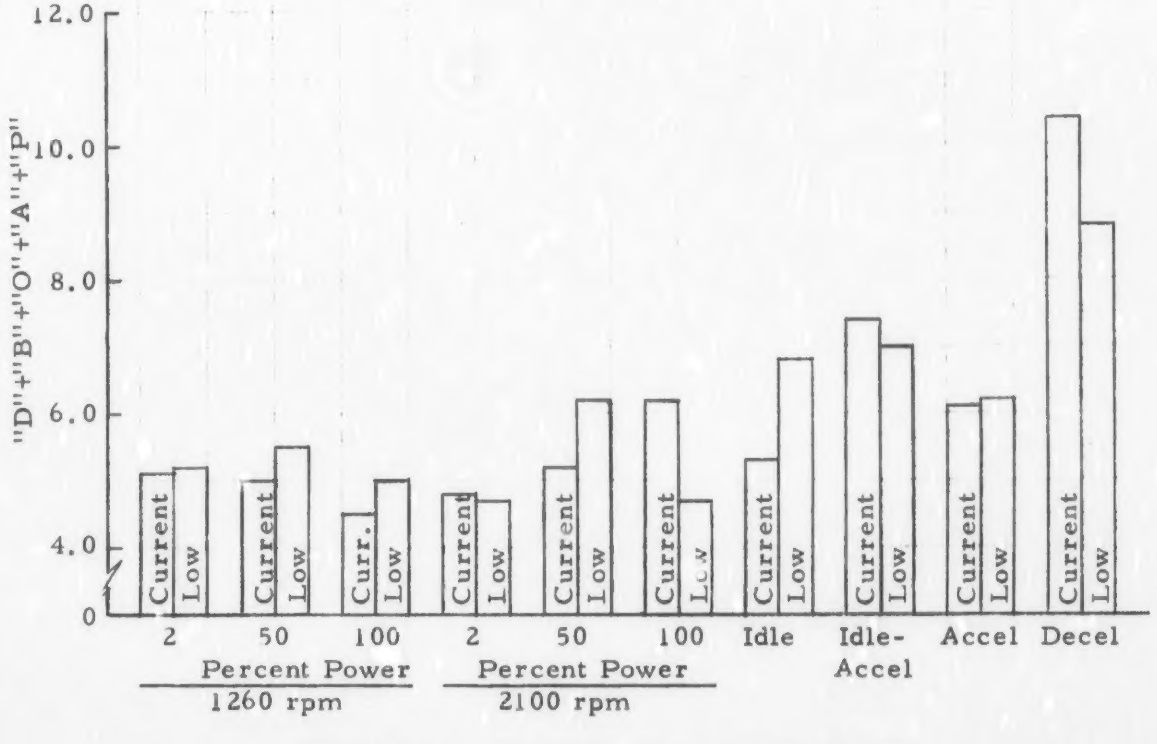


FIGURE 11. CUMMINS NTC-290 ENGINE DIESEL ODOR INTENSITY BY TRAINED PANEL

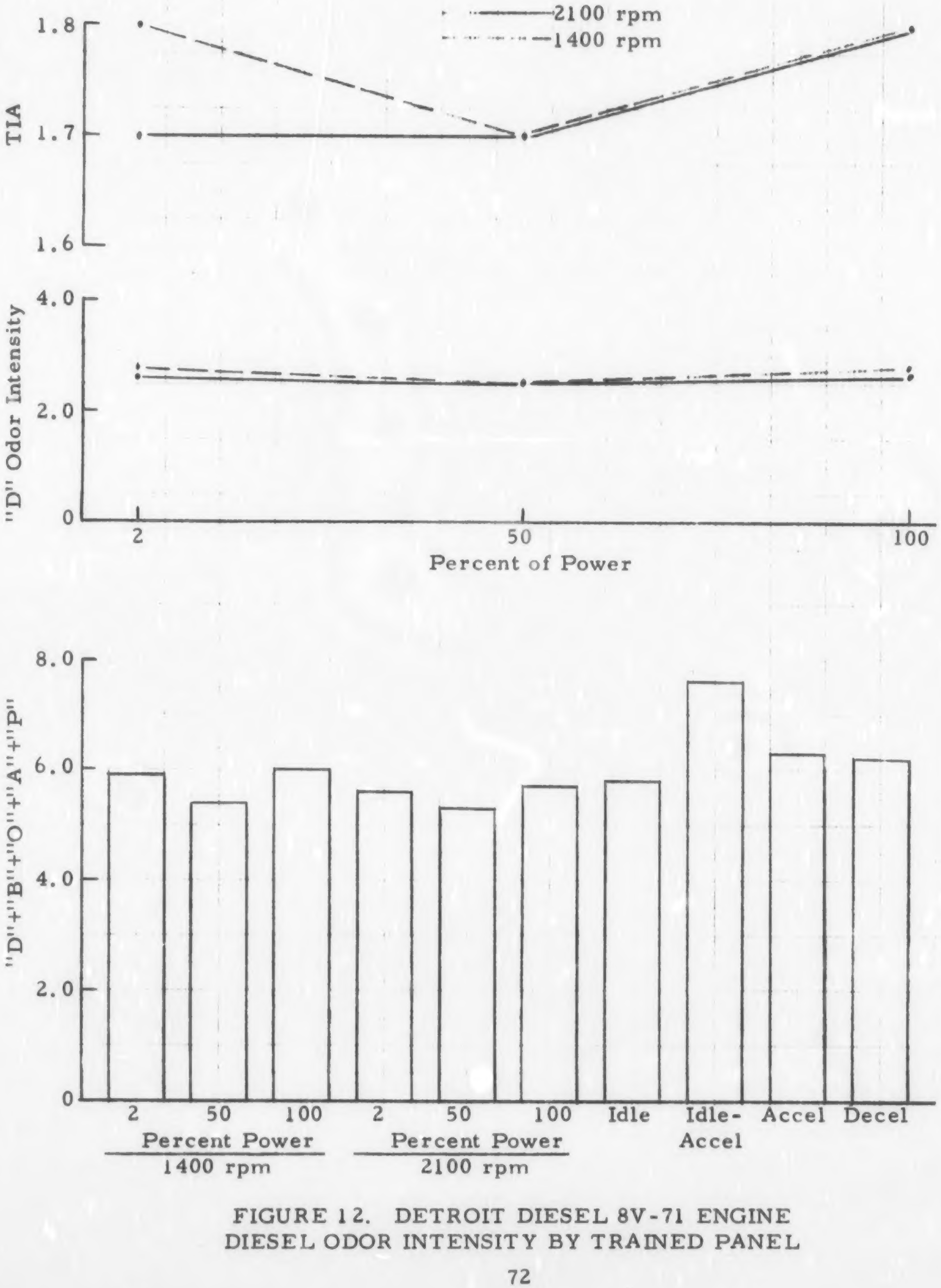


FIGURE 12. DETROIT DIESEL 8V-71 ENGINE
DIESEL ODOR INTENSITY BY TRAINED PANEL

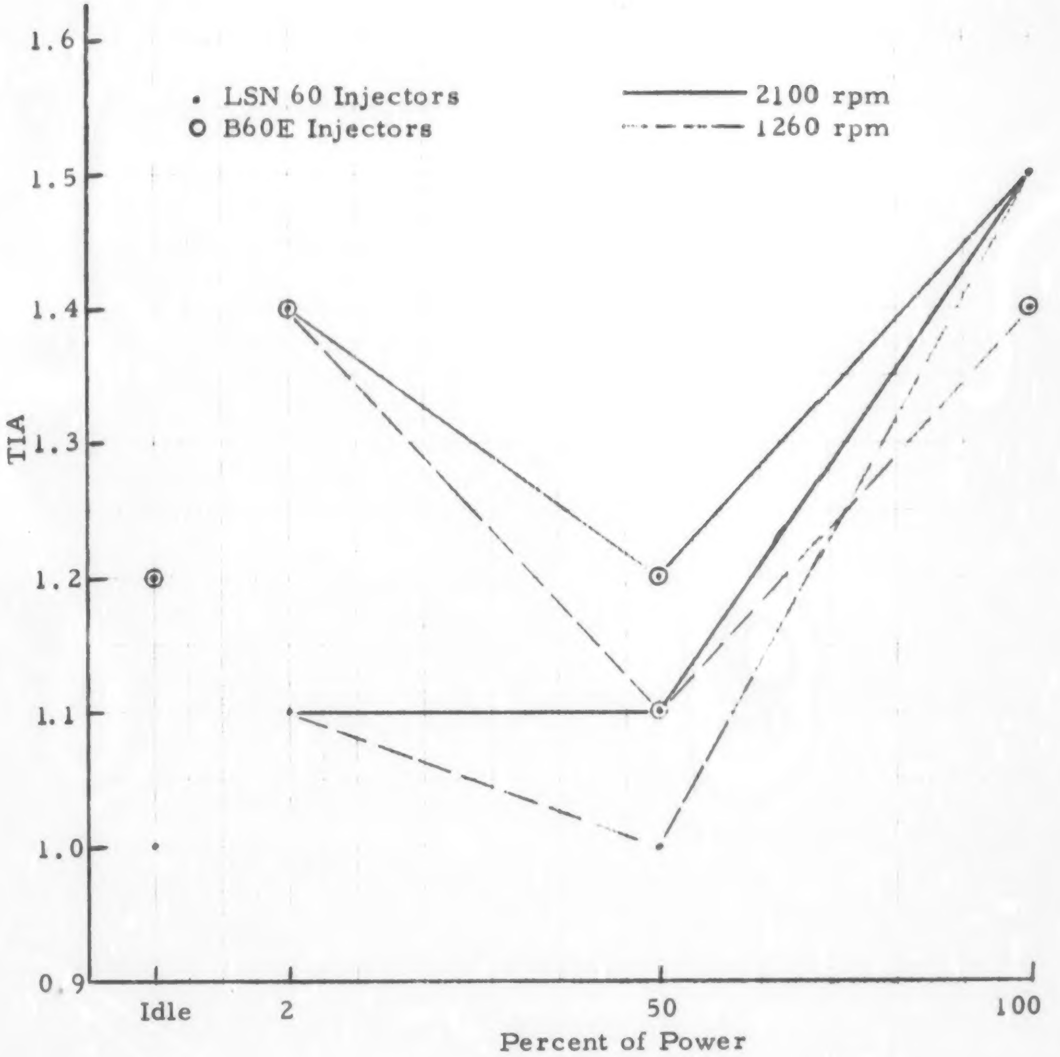


FIGURE 13. DETROIT DIESEL 6V-71 ENGINE DIESEL ODOR INTENSITY (TIA) BY DOAS METHOD

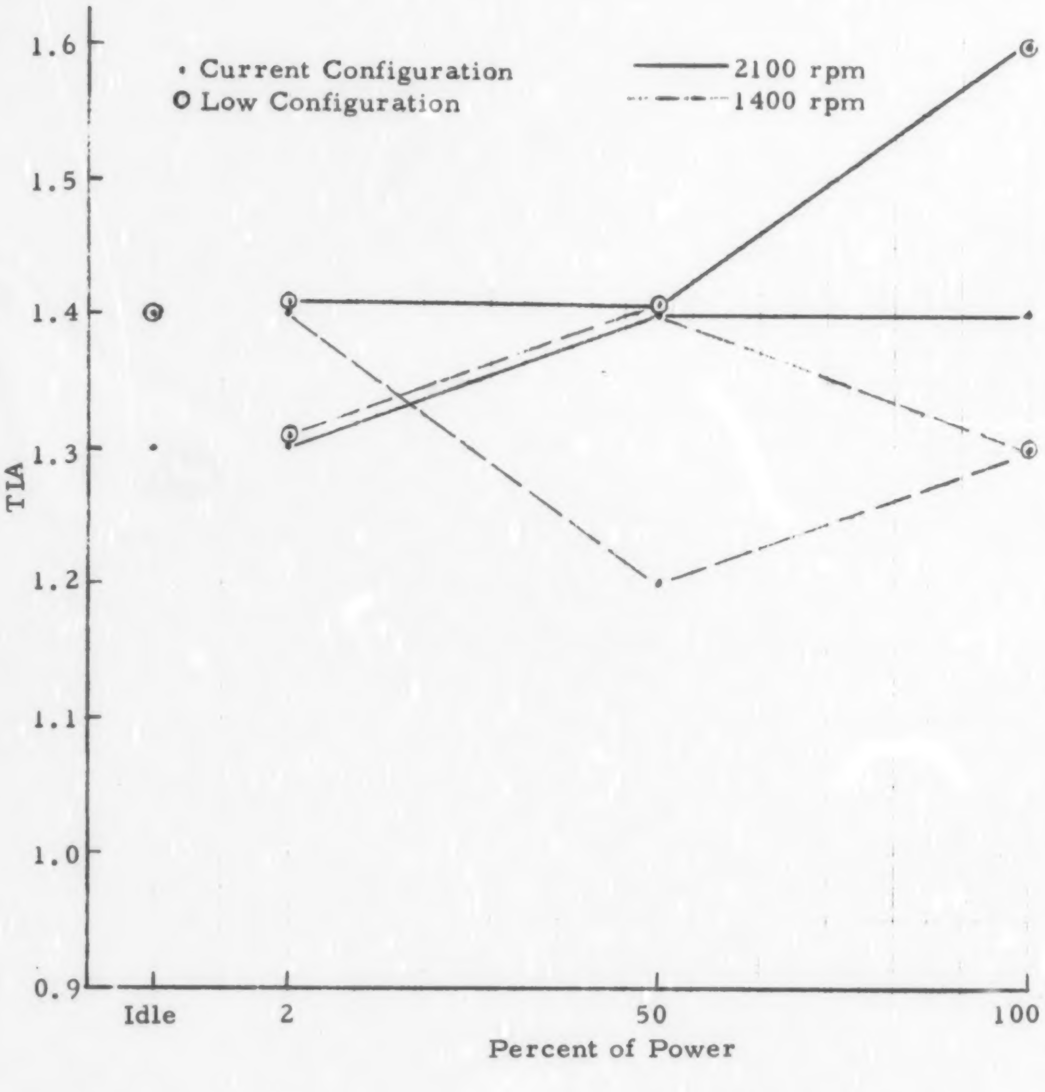


FIGURE 14. CUMMINS NTC-290 ENGINE
DIESEL ODOR INTENSITY (TIA) BY DOAS METHOD

(speed and load) for the DDAD 6V-71 and Cummins NTC-290 engine. This same type of graph is shown at the top of Figure 12 for the 8V-71 engine. The relationships are for the most part inconsistent with the panel rating versus operating condition, already discussed. For example, the smooth, consistent trends, shown on the top of Figures 10 and 11 in terms of "D" intensity are not repeated in Figures 13 and 14.

To illustrate the relationship between TIA and the "D" odor rating by trained panel, the average values by each were plotted in Figure 15 for the five engine configurations. In the range of "D"-2 to "D"-4.7 covered by these four engine configurations, there is no really satisfactory relationship present.

Much effort has been expended by SwRI staff to determine the LCO, LCA and TIA, using the most recent instrument modification and procedural changes recommended by Dr. Phil Levins of A. D. Little Co. The ability of the TIA measurement to predict or relate to "D" intensity from these five HD engines in a consistent way is of concern. It is difficult to justify odor measurement of HD diesel by this analysis method without substantial additional effort.

Use of the DOAS is currently restricted to steady state type operation since the sample must be accumulated over a period of time. Under the best set of conditions in a well equipped diesel emissions research laboratory, the relationship does not appear to be appropriate for anything beyond research purposes at this time. We continue to suggest its use in future odor projects as a matter of obtaining additional data for comparison-correlation purposes.

### 3. Detailed Hydrocarbons

Table 13 is a listing of the exhaust hydrocarbons, some of which are considered to be non-reactive in the atmosphere in terms of the formation of photochemical smog. These measurements were made at each of the seven steady-state operating points used for odor measurement. The engine operating data was previously listed on Table 12.

It is difficult to attribute the relative amounts of the various hydrocarbons in the exhaust to the change in engine configuration. If indeed one configuration produced more or less of a specific hydrocarbon, which change in the engine was responsible is difficult to say. Not enough is known about the effect of timing or injector design, in the case of the DDAD 6V-71 for example, to speculate or theorize on the trends.

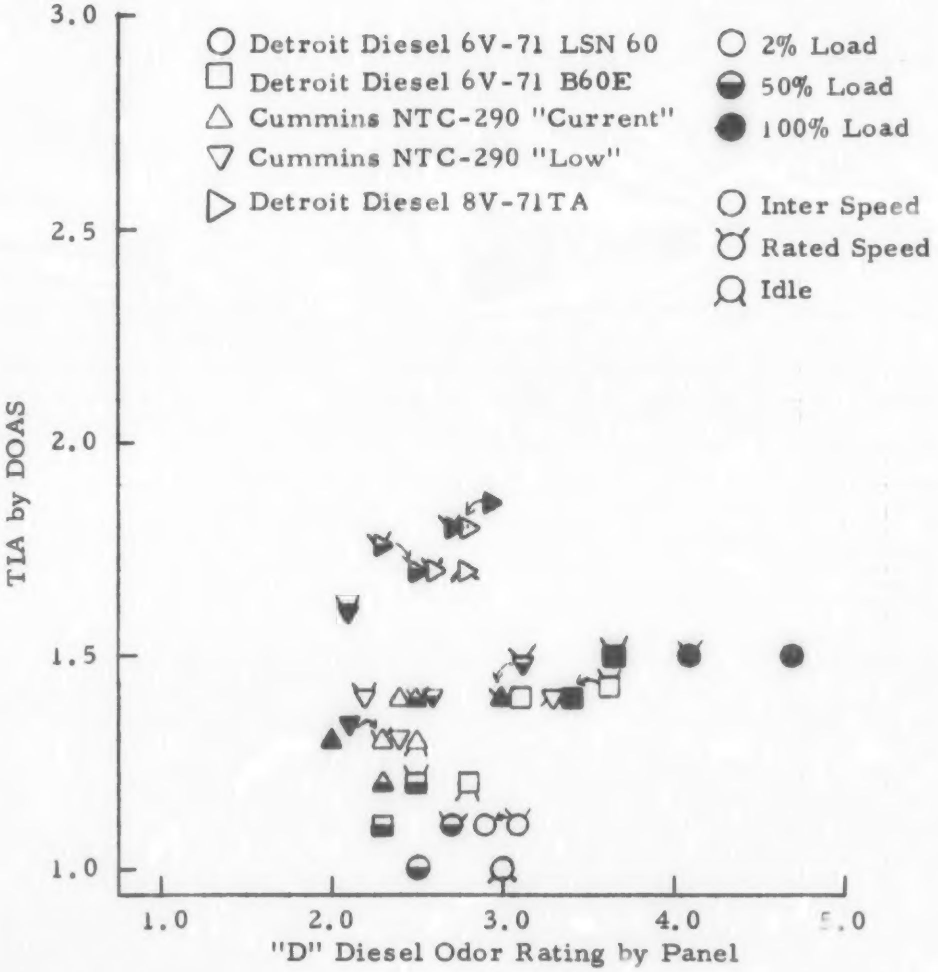


FIGURE 15. TIA BY DOAS VERSUS "D" DIESEL ODOR RATING BY TRAINED PANEL FOR FIVE HD DIESEL ENGINE CONFIGURATIONS

## TABLE 13. DISTRIBUTION OF EXHAUST HYDROCARBON EMISSIONS DURING STEADY-STATE ODOR TESTS, ppmC

| Engine Condition | Exhaust Emission | DDAD 6V-71(1) |  | Cummins NTC-290(1) |  | DDAD(2) |
|---|---|---|---|---|---|---|
|  |  | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| Intermediate Speed, 2% Load | Methane | 2.5 | 3.4 | 3.2 | 2.5 | 2.8 |
|  | Ethylene | 6.5 | 12.0 | 2.4 | 6.5 | 6.8 |
|  | Ethane | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 |
|  | Acetylene | 0.8 | 1.1 | 0.4 | 1.1 | 1.1 |
|  | Propane | tr | 0 | 0 | 0 | 0 |
|  | Propylene | 2.2 | 4.6 | 0.8 | 2.4 | 2.2 |
|  | Benzene(3) |  |  |  |  | 1.0 |
|  | Toluene(3) |  |  |  |  | 0.6 |
|  | FID HC(4) | 175 | 121 | 110 | 139 | 123 |
| Intermediate Speed, 50% Load | Methane | 2.3 | 1.8 | 1.5 | 0.8 | 1.8 |
|  | Ethylene | 4.2 | 2.0 | 0.9 | 2.8 | 3.2 |
|  | Ethane | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
|  | Acetylene | 0.9 | 0.5 | 0.3 | 0.4 | 0.7 |
|  | Propane | tr | 0 | 0 | 0 | 0 |
|  | Propylene | 1.7 | 0.7 | 0.9 | 1.4 | 1.4 |
|  | Benzene |  |  |  |  | 0.5 |
|  | Toluene |  |  |  |  | 0.1 |
|  | FID HC(4) | 235 | 77 | 64 | 93 | 89 |
| Intermediate Speed, 100% Load | Methane | 7.7 | 4.3 | 2.1 | 0.5 | 1.3 |
|  | Ethylene | 24.7 | 16.1 | 2.4 | 6.4 | 6.5 |
|  | Ethane | 1.3 | 0.5 | tr | tr | 0.2 |
|  | Acetylene | 1.1 | 1.2 | 0.3 | 0.5 | 1.0 |
|  | Propane | 0.3 | 0.1 | 0 | 1.5 | 0 |
|  | Propylene | 15.1 | 7.1 | 1.0 | 1.0 | 2.6 |
|  | Benzene |  |  |  |  | 0.7 |
|  | Toluene |  |  |  |  | 0.5 |
|  | FID HC(4) | 439 | 208 | 71 | 86 | 100 |
| High Speed, 2% Load | Methane | 2.2 | 3.5 | 2.3 | 1.1 | 2.0 |
|  | Ethylene | 6.2 | 14.1 | 2.0 | 2.5 | 5.3 |
|  | Ethane | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 |
|  | Acetylene | 0.7 | 1.6 | 0.4 | 0.5 | 0.9 |
|  | Propane | tr | 0 | 0.1 | 0 | 0 |
|  | Propylene | 2.3 | 5.4 | 0.7 | 0.9 | 2.2 |
|  | Benzene |  |  |  |  | 0.7 |
|  | Toluene |  |  |  |  | 0.6 |
|  | FID HC(4) | 199 | 130 | 72 | 90 | 92 |

TABLE 13. (Cont'd) DISTRIBUTION OF EXHAUST HYDROCARBON EMISSIONS DURING STEADY-STATE ODOR TESTS, ppmC

| Engine Condition | Exhaust Emission | DDAD 6V-71(1) |  | Cummins NTC-290(1) |  | DDAD(2) |
|---|---|---|---|---|---|---|
|  |  | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| High Speed, 50% Load | Methane | 1.6 | 1.5 | 1.5 | 1.1 | 1.3 |
|  | Ethylene | 3.6 | 2.9 | 1.6 | 3.6 | 3.2 |
|  | Ethane | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
|  | Acetylene | 0.6 | 0.6 | 0.4 | 0.5 | 0.8 |
|  | Propane | tr | 0 | 0.1 | 0 | 0 |
|  | Propylene | 1.4 | 1.1 | 0.5 | 1.9 | 1.2 |
|  | Benzene |  |  |  |  | 0.9 |
|  | Toluene |  |  |  |  | 1.0 |
|  | FID HC(4) | 259 | 92 | 64 | 95 | 111 |
| High Speed, 100% Load | Methane | 2.9 | 2.1 | 1.3 | 0.5 | 1.3 |
|  | Ethylene | 26.1 | 13.7 | 3.8 | 7.8 | 4.3 |
|  | Ethane | 0.7 | 0.3 | tr | 0.1 | 0 |
|  | Acetylene | 1.7 | 1.2 | 0.4 | 0.4 | 0.4 |
|  | Propane | 0.1 | 0 | 0 | 0 | 0 |
|  | Propylene | 13.8 | 6.0 | 1.4 | 4.1 | 2.2 |
|  | Benzene |  |  |  |  | 0.9 |
|  | Toluene |  |  |  |  | 0.5 |
|  | FID HC(4) | 333 | 143 | 83 | 88 | 85 |
| Idle | Methane | 2.7 | 2.7 | 3.0 | 2.3 | 3.0 |
|  | Ethylene | 6.4 | 7.2 | 4.5 | 8.3 | 4.8 |
|  | Ethane | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 |
|  | Acetylene | 0.9 | 0.8 | 0.6 | 0.8 | 0.9 |
|  | Propane | tr | 0.1 | 0 | 0 | 0 |
|  | Propylene |  |  |  |  | 0.9 |
|  | Benzene |  |  |  |  | 0.3 |
|  | FID HC(4) | 333 | 143 | 83 | 88 | 85 |
| Ambient(5) | Methane | 2.1 | 1.9 | 2.9 | 1.0 | 2.0 |

---

(1) Average of two runs

(2) Average of three runs

(3) Benzene and Toluene determinations made on DDAD 8V-71TA engine only

(4) Average exhaust HC from Table 11 for reference and comparison to individual HC, especially methane

(5) Representative of air in vicinity of engine intake. Other light hydrocarbons either non-measureable or in negligible concentrations <<0.1 ppmC

### 4. Aldehydes

Table 14 lists the aldehydes measured by the DNPH procedure for the DDAD 8V-71TA engine. In Section III, the DNPH procedure was described. The DNPH method was used for the first time by SwRI on this project and the 8V-71 engine was the first HD engine tested. The other two engines had completed the test program by the time the DNPH method was ready. The procedure took a substantial effort to prepare for and obtain laboratory calibration. The procedure continues to be troublesome and very time-consuming. It does have the great advantage over previous methods of giving insight into a number of the more common aldehydes and hopefully do them more accurately.

The aldehydes listed on Table 14 are expressed in concentration and in the same rates as particulates and sulfates, described later, of mg/hr, mg/kg fuel and mg/kw-hr. For the first time in the long-range project, data are available on acetaldehyde, acetone, isobutanal, crotonal, hexanal and benzaldehyde. In past projects, only formaldehyde and "aliphatic aldehydes", a functional grouping, were determined.

The net worth of these measurements will be better determined as more engines are measured by the same method. The analyses are time-consuming and expensive, making repetitive sampling prohibitive in cost. One must carefully select test conditions to give the maximum benefit. For example, each condition on Table 14 is a steady state odor test condition described earlier in this section. Only a single DNPH analysis of one sample is made for each of the seven conditions. The three replicate odor test runs for each condition are collected in a single bubbler to represent what the odor panel and other instrument measurements are based on. As more data is developed, it will be possible to evaluate the relationship of odor to various of the aldehydes by the computer regression techniques used earlier in this project.

## D. Particulate, Sulfate and $SO_2$ Results

The categories of particulate, sulfate and $SO_2$ are discussed in this subsection. Particulate and sulfate results share a common sampling basis while $SO_2$ and sulfate are basic to the sulfur balance. Table 15 is a summary listing of the particulate, sulfate, sulfuric acid, and sulfur dioxide emission rates for the five HD engines tested.

General methods of expressing the rate of emission for each contaminant are listed as follows; first, the concentration, in $mg/m^3$ or $\mu g/m^3$, for particulate and sulfates; then, a mass per unit of time, g/hr, rate, then two specific mass emission rates, g or mg per kg

## TABLE 14. ALDEHYDES BY DNPH FOR DDAD 8V-71TA ENGINE

| Condition | Emission Rate | Formaldehyde | Acetaldehyde | Acetone | Isobutanal | Crotonal | Hexanal | Benzaldehyde |
|---|---|---|---|---|---|---|---|---|
| 1400 rpm<br>2% load | $\mu g/m^3$ | 2223 | 777 | 1164 | 811 | 459 | 0 | 706 |
| | mg/hr | 1947 | 680 | 1020 | 711 | 402 | 0 | 618 |
| | mg/kg fuel | 314 | 110 | 165 | 115 | 65 | 0 | 100 |
| | mg/kw-hr | 556.3 | 194.3 | 291.4 | 203.1 | 114.9 | 0 | 176.6 |
| 1400 rpm<br>50% load | $\mu g/m^3$ | 1942 | 71 | 918 | 988 | 459 | 1589 | 635 |
| | mg/hr | 1969 | 72 | 931 | 1002 | 465 | 1611 | 644 |
| | mg/kg fuel | 82 | 3 | 39 | 42 | 19 | 67 | 27 |
| | mg/kw-hr | 21.1 | 0.8 | 10.0 | 10.8 | 5.0 | 17.3 | 6.9 |
| 1400 rpm<br>100% load | $\mu g/m^3$ | 3071 | 494 | 318 | 565 | 282 | 1412 | 353 |
| | mg/hr | 3880 | 624 | 401 | 714 | 357 | 1784 | 446 |
| | mg/kg fuel | 81 | 13 | 8 | 15 | 7 | 37 | 9 |
| | mg/kw-hr | 20.8 | 3.4 | 2.2 | 3.8 | 1.9 | 9.6 | 2.4 |
| Idle | $\mu g/m^3$ | 2118 | 565 | 459 | 1553 | 424 | 1094 | 0 |
| | mg/hr | 654 | 174 | 142 | 480 | 131 | 338 | 0 |
| | mg/kg fuel | 436 | 116 | 95 | 320 | 87 | 225 | 0 |
| | mg/kw-hr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2100 rpm<br>2% load | $\mu g/m^3$ | 1941 | 35 | 459 | 318 | 565 | 0 | 706 |
| | mg/hr | 2602 | 47 | 614 | 426 | 757 | 0 | 946 |
| | mg/kg fuel | 202 | 4 | 48 | 33 | 59 | 0 | 73 |
| | mg/kw-hr | 553.6 | 10.0 | 130.6 | 90.6 | 161.1 | 0 | 201.3 |
| 2100 rpm<br>50% load | $\mu g/m^3$ | 2400 | 35 | 600 | 1377 | 424 | 1236 | 177 |
| | mg/hr | 3692 | 54 | 923 | 2118 | 652 | 1901 | 272 |
| | mg/kg fuel | 104 | 2 | 26 | 60 | 18 | 54 | 8 |
| | mg/kw-hr | 29.2 | 0.4 | 7.3 | 16.8 | 5.2 | 15.1 | 2.2 |
| 2100 rpm<br>100% load | $\mu g/m^3$ | 2718 | 212 | 777 | 1659 | 247 | 1765 | 212 |
| | mg/hr | 4913 | 383 | 1404 | 2999 | 447 | 3190 | 383 |
| | mg/kg fuel | 80 | 6 | 23 | 49 | 7 | 52 | 6 |
| | mg/kw-hr | 19.4 | 1.5 | 5.6 | 11.9 | 1.8 | 12.6 | 1.5 |

## TABLE 15. SUMMARY OF PARTICULATE, SULFATE AND $SO_2$ FROM 47 mm GLASS AND FLUOROPORE FILTER SAMPLES

| | | | DDAD 6V-71 | | Cummins NTC 290 | | DDAD |
|---|---|---|---|---|---|---|---|
| Condition | Emission Rate | | LSN 60 | B 60E | "Current" | "Low" | 8V-71TA |
| Intermediate Speed, 2% Load | Particulate: | $mg/m^3$ | 27.48 | 29.11 | 17.8 | 17.5 | 29.29 |
| | | g/hr | 18.77 | 20.7 | 9.2 | 9.0 | 26.36 |
| | | g/kg fuel | 4.90 | 4.99 | 2.0 | 1.8 | 4.18 |
| | | g/kw-hr | 9.88 | 10.89 | 2.8 | 2.8 | 6.93 |
| | $SO_4^=$: | $\mu g/m^3$ | 345.5 | 555.5 | 577.4 | 1315.9 | 1129.9 |
| | | mg/hr | 235.8 | 395.3 | 298.6 | 680.9 | 1016.5 |
| | | mg/kg fuel | 61.8 | 95.5 | 66.3 | 139.0 | 161.2 |
| | | mg/kw-hr | 123.4 | 210.4 | 90.3 | 210.4 | 267.9 |
| | $H_2SO_4$: | $\mu g/m^3$ | 352.7 | 567.4 | 589.5 | 1343.6 | 1153.6 |
| | | mg/hr | 240.8 | 403.6 | 304.9 | 695.2 | 1037.9 |
| | | mg/kg fuel | 63.1 | 97.5 | 67.7 | 141.9 | 164.6 |
| | | mg/kw-hr | 126.0 | 214.8 | 92.2 | 214.8 | 273.6 |
| | $SO_2$: | g/hr | 7.97 | 7.26 | 23.4 | 29.6 | 27.8 |
| | | g/kg fuel | 2.08 | 1.75 | 5.2 | 6.0 | 4.4 |
| | | g/kw-hr | 4.19 | 3.82 | 7.1 | 9.3 | 7.3 |
| | S: % Recovery | $SO_2$ | 104.6 | 87.8 | 113.0 | 131.7 | 96.0 |
| | | $H_2SO_4$ | 2.1 | 3.19 | 0.96 | 2.0 | 2.3 |
| | | $SO_2+H_2SO_4$ | 106.7 | 90.9 | 113.9 | 133.7 | 98.3 |
| Intermediate Speed, 50% Load | Particulate: | $mg/m^3$ | 58.39 | 81.74 | 63.0 | 92.34 | 58.48 |
| | | g/hr | 39.7 | 56.45 | 36.7 | 60.67 | 60.73 |
| | | g/kg fuel | 3.15 | 4.59 | 1.8 | 2.4 | 2.57 |
| | | g/kw-hr | 0.79 | 1.17 | 0.4 | 0.8 | 0.6 |
| | $SO_4^=$. | $\mu g/m^3$ | 1026.7 | 681.4 | 4679.7 | 3832.0 | 4169.2 |
| | | mg/hr | 697.7 | 470.0 | 2726.0 | 2516.7 | 4334.9 |
| | | mg/kg fuel | 55.4 | 38.0 | 136.9 | 99.3 | 183.8 |
| | | mg/kw-hr | 14.0 | 9.74 | 32.9 | 31.9 | 45.6 |
| | $H_2SO_4$: | $\mu g/m^3$ | 1048.3 | 695.7 | 4777.9 | 3912.5 | 4256.8 |
| | | mg/hr | 712.3 | 479.8 | 2783.3 | 2569.6 | 4425.9 |
| | | mg/kg fuel | 56.6 | 38.8 | 139.8 | 101.3 | 187.6 |
| | | mg/kw-hr | 14.3 | 9.95 | 33.6 | 32.5 | 46.6 |
| | $SO_2$: | g/hr | 26.9 | 26.9 | 96.9 | 117.0 | 116.5 |
| | | g/kg fuel | 2.13 | 2.2 | 4.9 | 4.6 | 4.9 |
| | | g/kw-hr | 0.54 | 0.6 | 0.3 | 1.5 | 1.2 |
| | S: % Recovery | $SO_2$ | 106.8 | 109.2 | 105.9 | 100.4 | 107.4 |
| | | $H_2SO_4$ | 1.9 | 1.3 | 1.9 | 1.4 | 2.7 |
| | | $SO_2+H_2SO_4$ | 106.7 | 110.4 | 107.9 | 101.8 | 110.1 |

TABLE 15. (Cont'd) SUMMARY OF PARTICULATE, SULFATE AND $SO_2$ FROM 47 mm GLASS AND FLUOROPORE FILTER SAMPLES

| Condition | Emission Rate | | DDAD 6V-71 | | Cummins NTC 290 | | DDAD |
|---|---|---|---|---|---|---|---|
| | | | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| Intermediate Speed, 100% Load | Particulate: | mg/m$^3$ | 65.78 | 84.51 | 51.9 | 101.38 | 65.16 |
| | | g/hr | 45.43 | 58.66 | 38.6 | 79.74 | 86.57 |
| | | g/kg fuel | 1.85 | 2.50 | 1.0 | 2.03 | 1.80 |
| | | g/kw-hr | 0.48 | 0.62 | 0.2 | 0.49 | 0.46 |
| | $SO_4^=$: | $\mu$g/m$^3$ | 1309.3 | 1188.5 | 6802.2 | 4237.7 | 3021.6 |
| | | mg/hr | 903.9 | 824.6 | 5050.1 | 3331.6 | 4013.4 |
| | | mg/kg fuel | 36.9 | 35.1 | 131.5 | 84.7 | 83.5 |
| | | mg/kw-hr | 9.46 | 8.78 | 30.5 | 20.7 | 21.3 |
| | $H_2SO_4$: | $\mu$g/m$^3$ | 1336.8 | 1213.4 | 6945.0 | 4326.7 | 3085.1 |
| | | mg/hr | 922.9 | 841.9 | 5156.2 | 3401.5 | 4097.7 |
| | | mg/kg fuel | 37.6 | 35.9 | 134.3 | 86.5 | 85.2 |
| | | mg/kw-hr | 9.66 | 8.78 | 31.1 | 21.1 | 21.7 |
| | $SO_2$: | g/hr | 56.6 | 52.9 | 163.7 | 171.2 | 222.3 |
| | | g/kg fuel | 2.31 | 2.25 | 4.3 | 4.4 | 4.6 |
| | | g/kw-hr | 0.59 | 0.56 | 0.9 | 1.1 | 1.2 |
| | S:% Recovery | $SO_2$ | 115.4 | 112.8 | 92.7 | 94.7 | 100.6 |
| | | $H_2SO_4$ | 1.2 | 1.17 | 1.9 | 1.2 | 1.2 |
| | | $SO_2+H_2SO_4$ | 116.7 | 114.0 | 94.7 | 95.9 | 101.8 |
| Idle | Particulate: | mg/m$^3$ | 33.6 | 40.2 | 11.3 | 13.7 | 6.7 |
| | | g/hr | 6.7 | 8.5 | 2.5 | 2.9 | 1.7 |
| | | g/kg fuel | 6.4 | 8.5 | 2.3 | 1.9 | 1.1 |
| | | g/kw-hr | ---- | ---- | ---- | ---- | 0 |
| | $SO_4^=$: | $\mu$g/m$^3$ | 543.1 | 338.4 | 749.4 | 1675.7 | 1187.0 |
| | | mg/hr | 107.7 | 71.4 | 162.1 | 362.7 | 301.8 |
| | | mg/kg fuel | 102.4 | 68.7 | 142.3 | 253.8 | 195.7 |
| | | mg/kw-hr | R | R | R | R | |
| | $H_2SO_4$: | $\mu$g/m$^3$ | 554.6 | 345.5 | 765.1 | 1710.8 | 1212.9 |
| | | mg/hr | 109.9 | 72.9 | 165.5 | 370.3 | 308.1 |
| | | mg/kg fuel | 104.5 | 70.1 | 145.3 | 259.2 | 195.7 |
| | | mg/kw-hr | R | R | R | R | |
| | $SO_2$: | g/hr | 3.72 | 3.3 | 7.1 | 7.5 | 7.3 |
| | | g/kg fuel | 3.58 | 3.3 | 6.5 | 5.0 | 4.9 |
| | | g/kw-hr | ---- | ---- | ---- | ---- | 0 |
| | S:%Recovery | $SO_2$ | 177.1 | 159.2 | 136.0 | 113.5 | 102.7 |
| | | $H_2SO_4$ | 3.42 | 2.3 | 2.1 | 3.7 | 2.8 |
| | | $SO_2+H_2SO_4$ | 180.5 | 161.5 | 138.1 | 117.2 | 105.6 |

## TABLE 15. (Cont'd) SUMMARY OF PARTICULATE, SULFATE AND $SO_2$ FROM 47 mm GLASS AND FLUOROPORE FILTER SAMPLES

| | | | DDAD 6V-71 | | Cummins NTC 290 | | DDAD |
|---|---|---|---|---|---|---|---|
| Condition | Emission Rate | | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| High Speed, 100% Load | Particulate: | $mg/m^3$ | 126.4 | 151.1 | 35.3 | 54.00 | 63.2 |
| | | g/hr | 139.3 | 169.6 | 45.0 | 74.17 | 122.0 |
| | | g/kg fuel | 4.1 | 5.1 | 0.8 | 1.4 | 2.0 |
| | | g/kw-hr | 1.0 | 1.3 | 0.2 | 0.4 | 0.5 |
| | $SO_4^=$: | $\mu g/m^3$ | 2486.6 | 3241.6 | 5073.5 | 4675.7 | 7003.8 |
| | | mg/hr | 2737.9 | 3635.0 | 6460.9 | 6420.1 | 13526.3 |
| | | mg/kg fuel | 80.2 | 108.4 | 123.3 | 118.9 | 219.3 |
| | | mg/kw-hr | 20.6 | 27.9 | 28.9 | 31.7 | 53.9 |
| | $H_2SO_4$: | $\mu g/m^3$ | 2538.8 | 3309.6 | 5180.0 | 4773.9 | 7150.8 |
| | | mg/hr | 2795.4 | 3711.4 | 6596.6 | 6555.0 | 13810.3 |
| | | mg/kg fuel | 81.8 | 110.7 | 125.9 | 121.4 | 223.9 |
| | | mg/kw-hr | 20.9 | 28.4 | 29.5 | 32.4 | 55.1 |
| | $SO_2$: | g/hr | 60.2 | 54.8 | 249.3 | 233.8 | 294.3 |
| | | g/kg fuel | 1.7 | 1.6 | 4.7 | 4.3 | 4.8 |
| | | g/kw-hr | 0.45 | 0.4 | 1.1 | 1.2 | 1.2 |
| | S: % Recovery | $SO_2$ | 88.2 | 81.8 | 103.5 | 94.3 | 103.8 |
| | | $H_2SO_4$ | 2.68 | 3.6 | 1.8 | 1.7 | 3.2 |
| | | $SO_2+H_2SO_4$ | 90.9 | 85.4 | 105.3 | 96.0 | 107.0 |
| High Speed, 50% Load | Particulate: | $mg/m^3$ | 104.9 | 143.7 | 54.2 | 95.39 | 59.7 |
| | | g/hr | 116.3 | 159.3 | 54.8 | 90.64 | 97.6 |
| | | g/kg fuel | 5.7 | 7.6 | 1.8 | 2.7 | 2.8 |
| | | g/kw-hr | 1.68 | 2.4 | 0.5 | 0.9 | 0.8 |
| | $SO_4^=$: | $\mu g/m^3$ | 1529.4 | 1908.5 | 4578.9 | 4475.3 | 4148.7 |
| | | mg/hr | 1694.9 | 2118.2 | 4625.2 | 4250.8 | 6779.2 |
| | | mg/kg fuel | 82.6 | 101.6 | 150.3 | 125.1 | 191.9 |
| | | mg/kw-hr | 24.6 | 31.4 | 41.4 | 39.9 | 54.1 |
| | $H_2SO_4$: | $\mu g/m^3$ | 1561.5 | 1948.5 | 4675.1 | 4569.2 | 4235.8 |
| | | mg/hr | 1730.5 | 2162.7 | 4722.3 | 4340.0 | 6921.6 |
| | | mg/kg fuel | 84.3 | 103.8 | 153.4 | 127.7 | 195.9 |
| | | mg/kw-hr | 25.1 | 32.1 | 42.3 | 40.8 | 55.2 |
| | $SO_2$: | g/hr | 37.5 | 38.5 | 117.8 | 125.3 | 170.8 |
| | | g/kg fuel | 1.82 | 1.84 | 3.8 | 3.7 | 4.8 |
| | | g/kw-hr | 0.54 | 0.57 | 1.1 | 1.2 | 1.4 |
| | S: % Recovery | $SO_2$ | 91.4 | 92.5 | 83.3 | 80.2 | 105.2 |
| | | $H_2SO_4$ | 2.8 | 3.4 | 2.2 | 1.8 | 2.8 |
| | | $SO_2+H_2SO_4$ | 94.1 | 95.9 | 85.5 | 82.1 | 107.9 |

TABLE 15. (Cont'd) SUMMARY OF PARTICULATE, SULFATE AND $SO_2$ FROM 47 mm GLASS AND FLUOROPORE FILTER SAMPLES

| | | | DDAD 6V-71 | | Cummins NTC 290 | | DDAD |
|---|---|---|---|---|---|---|---|
| Condition | Emission Rate | | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| High Speed, 2% Load | Particulate: | mg/m$^3$ | 86.6 | 104.49 | 39.5 | 38.2 | 49.6 |
| | | g/hr | 94.4 | 115.74 | 31.3 | 27.7 | 66.7 |
| | | g/ kg fuel | 10.9 | 13.0 | 3.3 | 2.8 | 5.4 |
| | | g/kw-hr | 34.9 | 44.5 | 6.9 | 6.8 | 13.3 |
| | $SO_4^=$: | µg/m$^3$ | 947.7 | 1116.1 | 1387.9 | 2755.8 | 1406.5 |
| | | mg/hr | 1033.0 | 1236.2 | 1101.4 | 1997.1 | 1891.8 |
| | | mg/kg fuel | 120.1 | 138.3 | 116.3 | 203.5 | 153.3 |
| | | mg/kw-hr | 387.9 | 473.6 | 245.3 | 490.4 | 381.5 |
| | $H_2SO_4$: | µg/m$^3$ | 967.6 | 1139.5 | 1417.0 | 2813.6 | 1436.1 |
| | | mg/hr | 1054.7 | 1262.2 | 1124.5 | 2038.9 | 1931.6 |
| | | mg/kg fuel | 122.6 | 141.2 | 118.8 | 207.8 | 156.6 |
| | | mg/kw-hr | 396.1 | 483.5 | 250.5 | 500.7 | 389.5 |
| | $SO_2$: | g/hr | 20.7 | 18.4 | 47.9 | 47.2 | 61.2 |
| | | g/kg fuel | 2.41 | 2.1 | 5.0 | 4.8 | 5.0 |
| | | g/kw-hr | 7.7 | 7.1 | 10.6 | 11.5 | 12.2 |
| | S: % Recovery | $SO_2$ | 120.6 | 103.3 | 110.2 | 104.6 | 108.0 |
| | | $H_2SO_4$ | 4.0 | 4.6 | 1.69 | 2.9 | 2.2 |
| | | $SO_2$+$H_2SO_4$ | 124.6 | 108.0 | 111.9 | 107.6 | 110.2 |

fuel consumed and g or mg per kw-hr of work produced. These are commonly known as "fuel specific" and "brake specific" emission rates.

Also listed on Table 15 are percent recoveries in terms of $SO_2$, $H_2SO_4$ and $SO_2$ plus $H_2SO_4$. It is the combined $H_2SO_4$ plus $SO_2$ recovery, as a percent of sulfur in the fuel consumed, that represents the sulfur balance. The goal for such recoveries is to be within ±10 percent of the theoretical sulfur consumed by the engine.

Table 16 is a summary of the engine operating conditions measured during the sampling for particulate and sulfate. The values are averaged for the replicate tests and may be used to represent typical operation For example, the fuel rate or air flow rate may be used in determining emissions per day given a usage factor, cycle of operation and the emission rates of Table 15. For purposes of additional discussion, the results are graphed by engine make.

### 1. DDAD 6V-71

Figures 16, 17 and 18 are graphs of particulate, sulfate ($SO_4^=$) and $SO_2$ rates, given in Table 15, for the 6V-71N engine. The rates are plotted against power level at the rated and intermediate engine speeds for both LSN 60 - 1.470 timing and B60E - 1.500 timing configurations. Note that the particulate, sulfate and $SO_2$ mass per unit of time all increase mostly linearly with an increase in power. To produce this power requires an increase in fuel so these trends are understandable.

However, when the mass per unit of fuel consumed are plotted, then the particulate and sulfate mostly decreased with an increase in power. The concentrations of particulate, sulfate or $SO_2$ all increased as the power was increased. The principal engine conditions of power output, fuel rate and air flow are graphed in Figure 19 for this engine and series of tests.

### 2. Cummins NTC-290

Figures 20, 21 and 22 are graphs of particulate, sulfate and $SO_2$ rates for the Cummins NTC-290 engine. As with the 6V-71, the rates are from Table 15 data and are plotted against power level for the "current" and "low" emission configurations. As with the 6V-71 engine, particulate, sulfate and $SO_2$ mass emissions per unit of time increased with power level. One exception was the particulate rate, g/hr, Figure 20, for the 2100 rpm where the 50 percent power point was the maximum value of those measured.

## TABLE 16. SUMMARY OF ENGINE OPERATING CONDITIONS 47mm GLASS AND FLUOROPORE FILTER TESTS

| Condition | Engine Operation | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|---|
| | | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| Intermediate Speed, 2% Load | Engine Speed, rpm | 1260 | 1260 | 1400 | 1400 | 1400 |
| | Power Output, kw | 1.9 | 1.9 | 3.3 | 3.2 | 3.5 |
| | Fuel Rate, kg/hr | 3.8 | 4.2 | 4.5 | 4.9 | 6.2 |
| | Air Rate, kg/min | 13.5 | 14.1 | 10.2 | 10.3 | 17.5 |
| | BSFC, kg/kw-hr | 2.016 | 2.184 | 1.364 | 1.531 | 1.666 |
| | Inlet Temp. °C | 28.9 | 23.9 | 26.7 | 33.3 | 23.3 |
| | Inlet Rest., mm Hg | 21.5 | 23.0 | 11.2 | 9.7 | 13.1 |
| | Exh. Rest., mm Hg | 52.3 | 49.8 | 20.3 | 15.2 | 30.5 |
| Intermediate Speed 50% Load | Engine Speed, rpm | 1260 | 1260 | 1400 | 1400 | 1400 |
| | Power Output, kw | 49.8 | 48.2 | 82.8 | 79.0 | 93.1 |
| | Fuel Rate, kg/hr | 12.6 | 12.3 | 19.9 | 25.4 | 23.9 |
| | Air Rate, kg/min | 13.3 | 13.5 | 11.3 | 12.8 | 20.3 |
| | BSFC, kg/kw-hr | 0.253 | 0.261 | 0.240 | 0.322 | 0.256 |
| | Inlet Temp, °C | 32.2 | 25.00 | 27.2 | 31.7 | 24.4 |
| | Inlet Rest., mm Hg | 21.5 | 21.7 | 13.6 | 13.8 | 15.9 |
| | Exh. Rest., mm Hg | 65.0 | 64.8 | 26.7 | 27.9 | 43.2 |
| Intermediate Speed 100% Load | Engine Speed, rpm | 1260 | 1260 | 1400 | 1400 | 1400 |
| | Power Output, kw | 95.5 | 94. | 165.6 | 161.1 | 186.2 |
| | Fuel Rate, kg/hr | 24.5 | 23.5 | 38.4 | 39.3 | 47.9 |
| | Air Rate, kg/min | 13.3 | 13.4 | 14.1 | 15.2 | 25.3 |
| | BSFC, kg/km-hr | 0.257 | 0.25 | 0.232 | 0.244 | 0.257 |
| | Inlet Temp, °C | 33.9 | 26.7 | 27.2 | 31.7 | 25.6 |
| | Inlet Rest., mm Hg | 21.3 | 21.9 | 18.9 | 17.8 | 24.3 |
| | Exh. Rest., mm Hg | 79.5 | 79.8 | 33.0 | 33.0 | 53.3 |
| Idle | Engine Speed, rpm | 430 | 430 | 615 | 615 | 480 |
| | Power Output | 0 | 0 | 0 | 0 | 0 |
| | Fuel Rate, kg,hr | 1.0 | 1.0 | 1.1 | 1.5 | 1.5 |
| | Air Rate, kg/min | 4.0 | 4.2 | 4.3 | 4.3 | 6.2 |
| | BSFC, kg/kw-hr | ---- | --- | ---- | ---- | ----- |
| | Inlet Temp, °C | 32.2 | 27.8 | 26.7 | 31.7 | 26.1 |
| | Inlet Rest., mm Hg | 3.7 | 4.7 | 2.6 | 2.2 | 2.4 |
| | Exh. Rest., mm Hg | 23.6 | 25.4 | 12.7 | 12.7 | 25.4 |
| High Speed 100% Load | Engine Speed, rpm | 2100 | 2100 | 2100 | 2100 | 2100 |
| | Power Output | 133.1 | 130.5 | 223.4 | 202.6 | 252.6 |
| | Fuel Rate, kg/hr | 34.1 | 33.5 | 52.4 | 53.9 | 61.7 |
| | Air Rate, kg/min | 21.4 | 21.7 | 24.5 | 26.7 | 36.2 |
| | BSFC, kg/kw-hr | 0.256 | 0.257 | 0.235 | 0.266 | 0.244 |
| | Inlet Temp, °C | 34.4 | 27.8 | 27.2 | 31.1 | 26.1 |
| | Inlet Rest., mm Hg | 47.1 | 47.1 | 48.2 | 45.8 | 47.6 |
| | Exh. Rest., mm Hg | 102.9 | 102.9 | 64.0 | 63.5 | 88.9 |

TABLE 16. SUMMARY OF ENGINE OPERATING CONDITIONS
47mm GLASS AND FLUOROPORE FILTER TESTS (CONT'D.)

| | | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|---|
| Condition | Engine Operation | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| High Speed 50% Load | Engine Speed, rpm | 2100 | 2100 | 2100 | 2100 | 2100 |
| | Power Output | 68.9 | 67.3 | 111.7 | 106.5 | 126.3 |
| | Fuel Rate, kg/hr | 20.5 | 20.9 | 30.8 | 34.0 | 35.5 |
| | Air Rate, kg/min | 21.7 | 21.8 | 19.6 | 18.5 | 30.8 |
| | BSFC, kg/kw-hr | 0.298 | 0.311 | 0.276 | 0.319 | 0.281 |
| | Inlet Temp, °C | 32.2 | 28.3 | 27.2 | 30.0 | 25.5 |
| | Inlet Rest., mm Hg | 47.5 | 47.5 | 32.7 | 40.0 | 35.5 |
| | Exh. Rest., mm Hg | 90.0 | 92.0 | 45.7 | 45.7 | 63.5 |
| High Speed 2% Load | Engine Speed, rpm | 2100 | 2100 | 2100 | 2100 | 2100 |
| | Power Output | 2.7 | 2.6 | 4.5 | 4.1 | 4.7 |
| | Fuel Rate, kg/hr | 8.6 | 8.9 | 9.5 | 9.8 | 12.9 |
| | Air Rate, kg/min | 21.9 | 21.8 | 15.6 | 14.4 | 26.8 |
| | BSFC, kg/kw-hr | 3.185 | 3.423 | 2.111 | 2.390 | 2.744 |
| | Inlet Temp, °C | 34.4 | 27.2 | 27.2 | 27.8 | 24.4 |
| | Inlet Rest., mm Hg | 48.2 | 48.2 | 22.2 | 55.1 | 26.0 |
| | Exh. Rest., mm Hg | 78.2 | 80.0 | 26.7 | 27.9 | 38.1 |

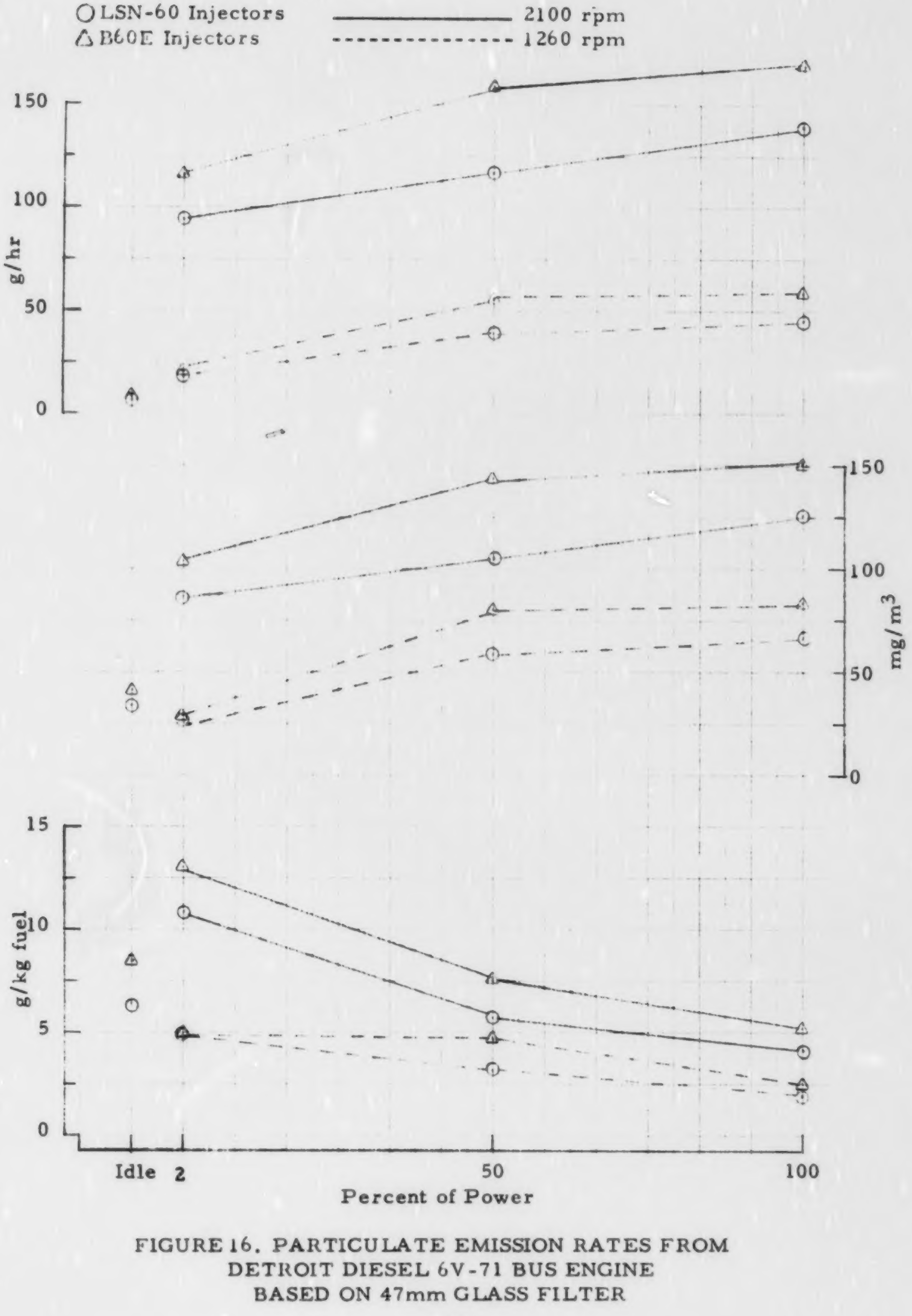


FIGURE 16. PARTICULATE EMISSION RATES FROM DETROIT DIESEL 6V-71 BUS ENGINE BASED ON 47mm GLASS FILTER

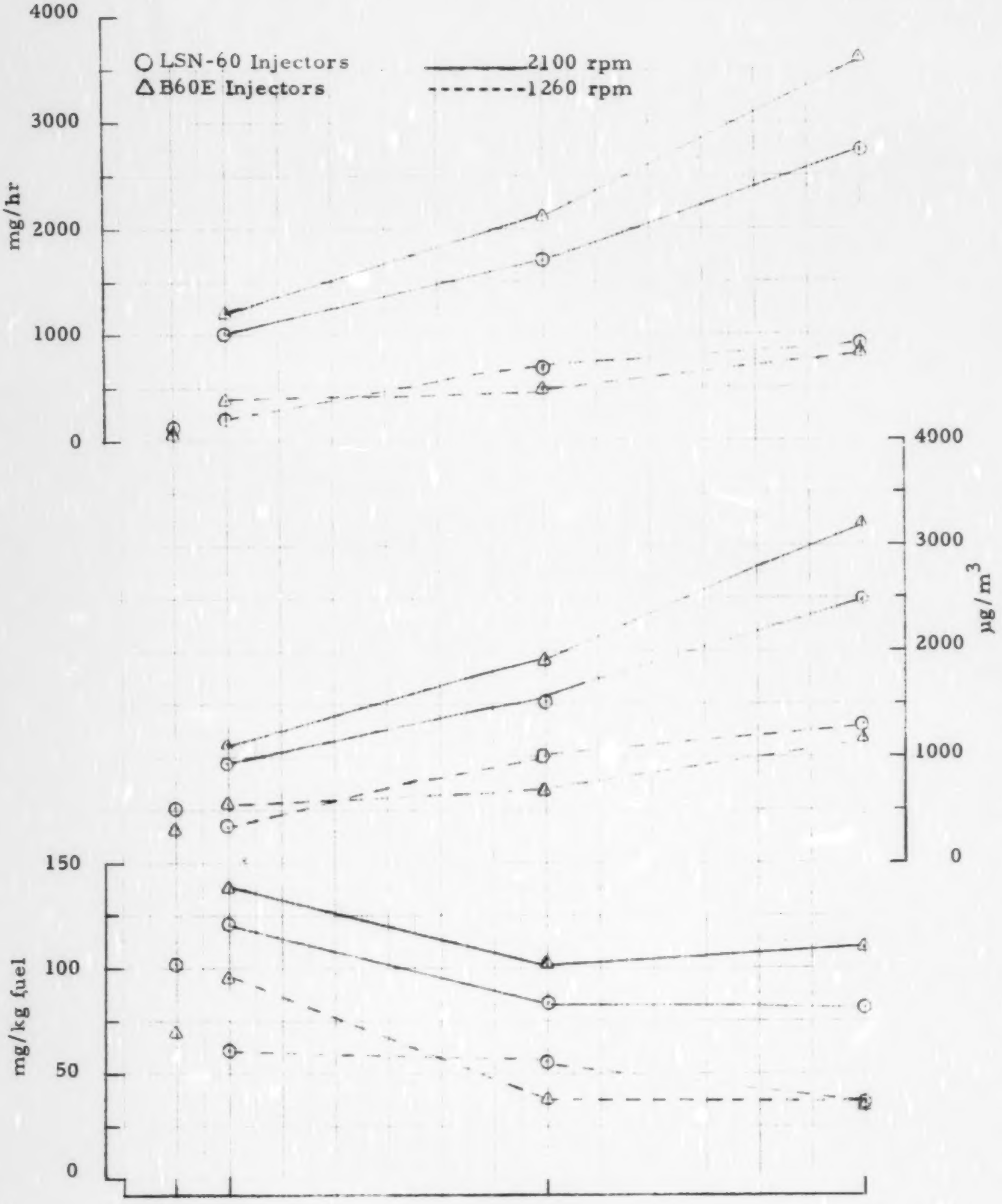


FIGURE 17. SULFATE ($SO_4^=$) EMISSION RATES FROM DETROIT DIESEL 6V-71 BUS ENGINE BASED ON 47mm FLUOROPORE FILTER

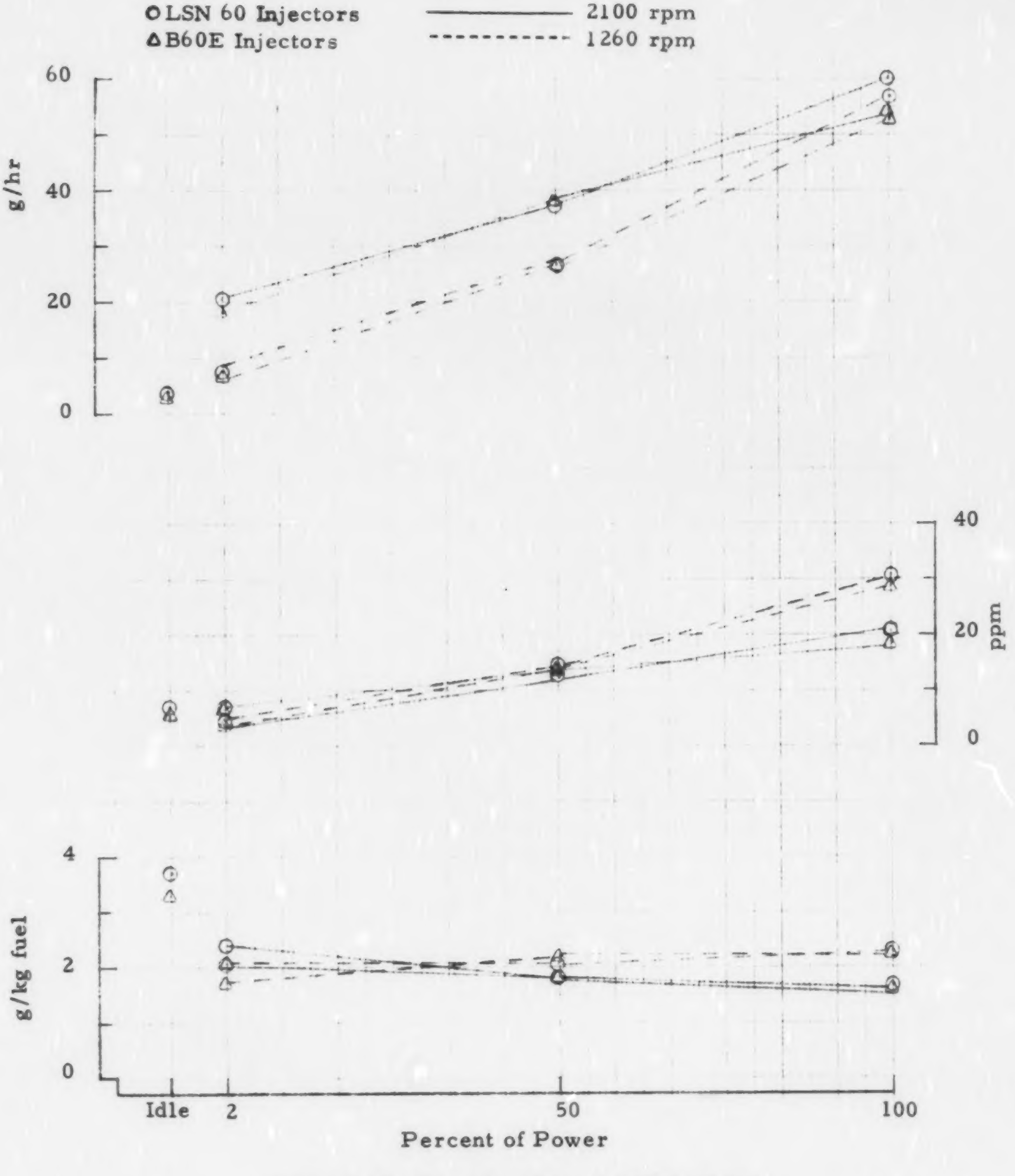


FIGURE 18. $SO_2$ EMISSION RATES FROM DETROIT DIESEL 6V-71 BUS ENGINE

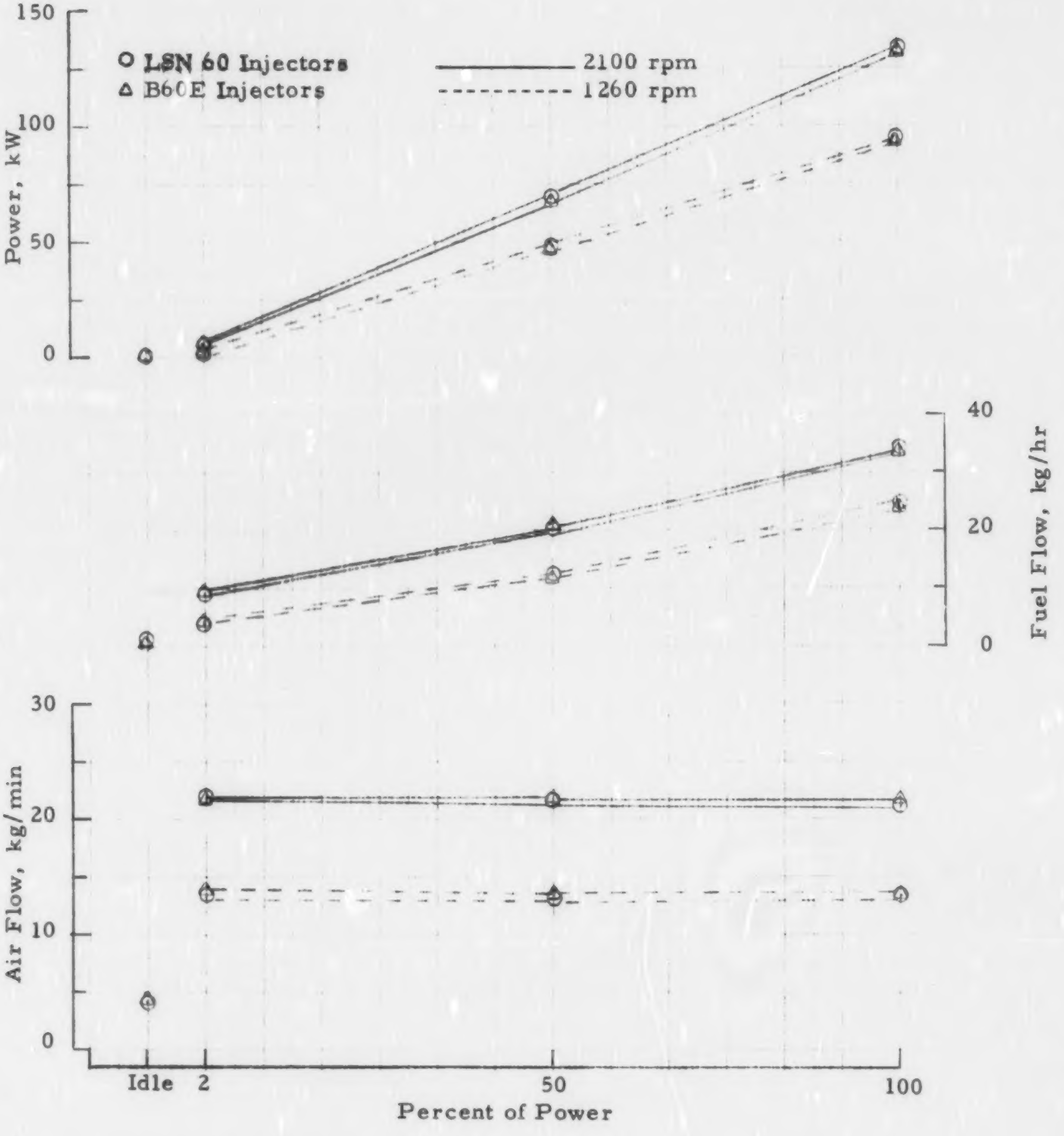


FIGURE 19. POWER OUTPUT FUEL AND AIR RATES FROM DETROIT DIESEL 6V-71 BUS ENGINE DURING 7 MODE TESTS

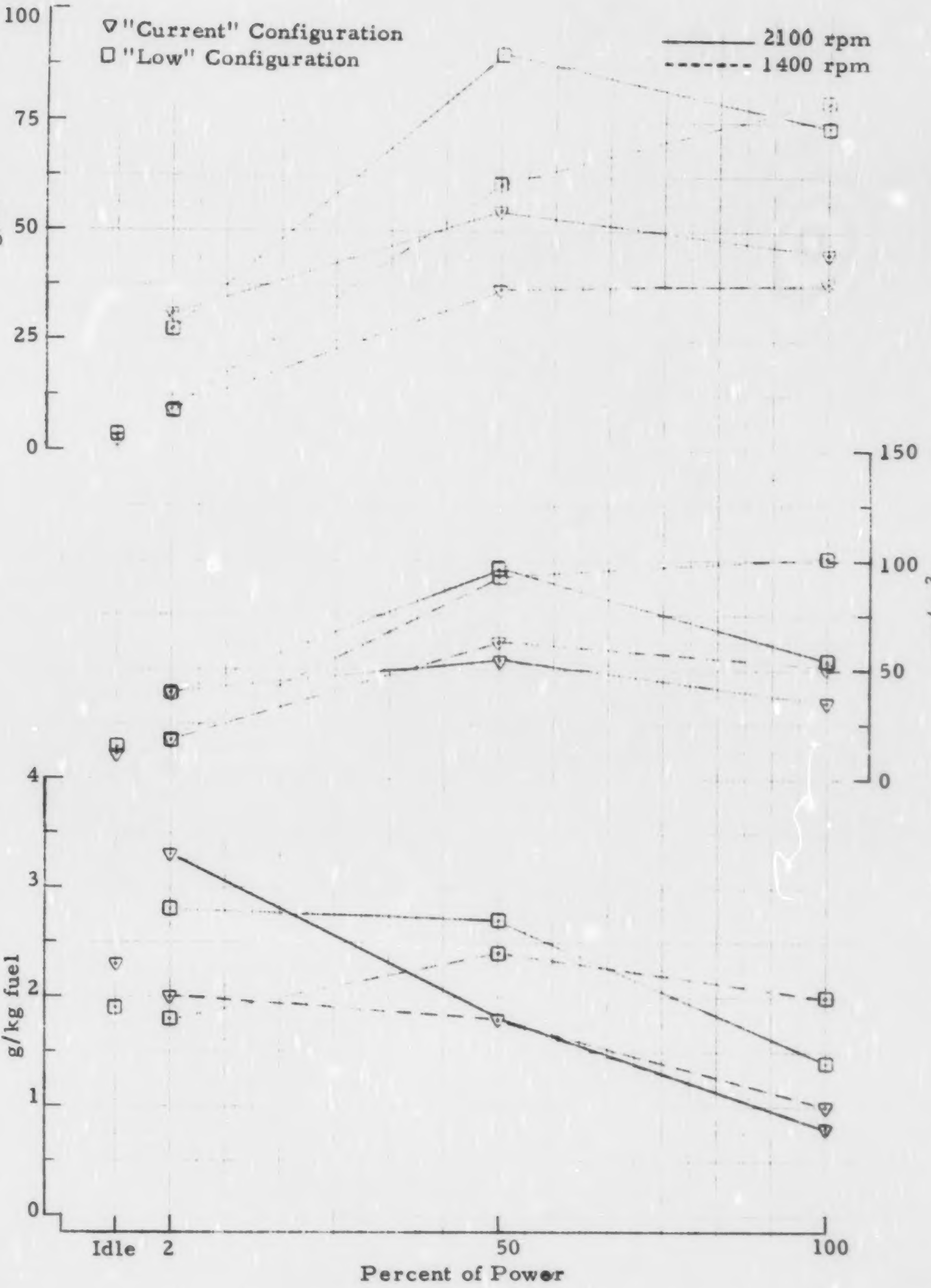


FIGURE 20. PARTICULATE EMISSION RATES FROM CUMMINS NTC-290 TRUCK ENGINE BASED ON 47mm GLASS FILTER

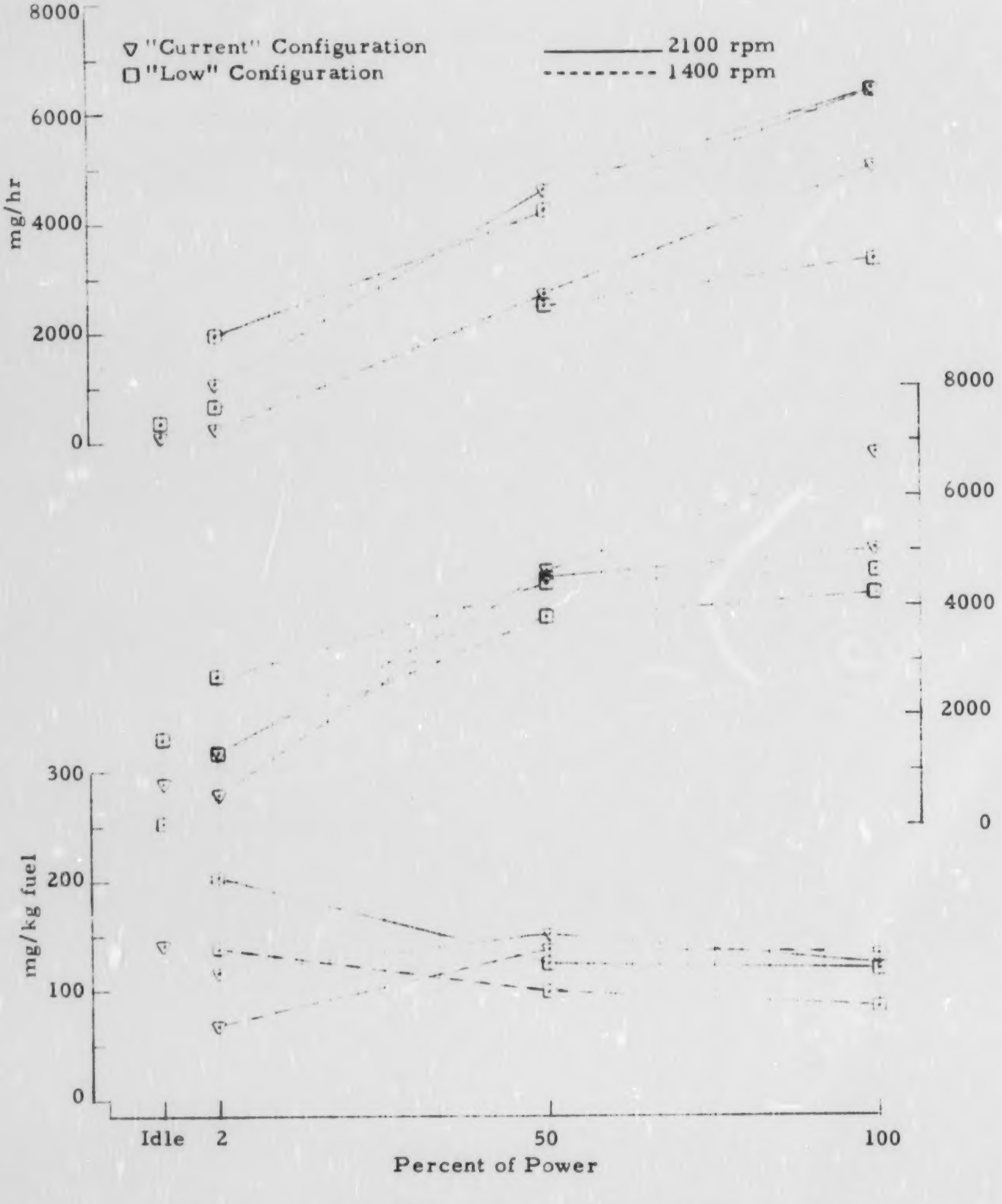


FIGURE 21. SULFATE ($SO_4^=$) EMISSION RATES FROM CUMMINS NTC-290 TRUCK ENGINE BASED ON 47mm FLUOROPORE FILTER

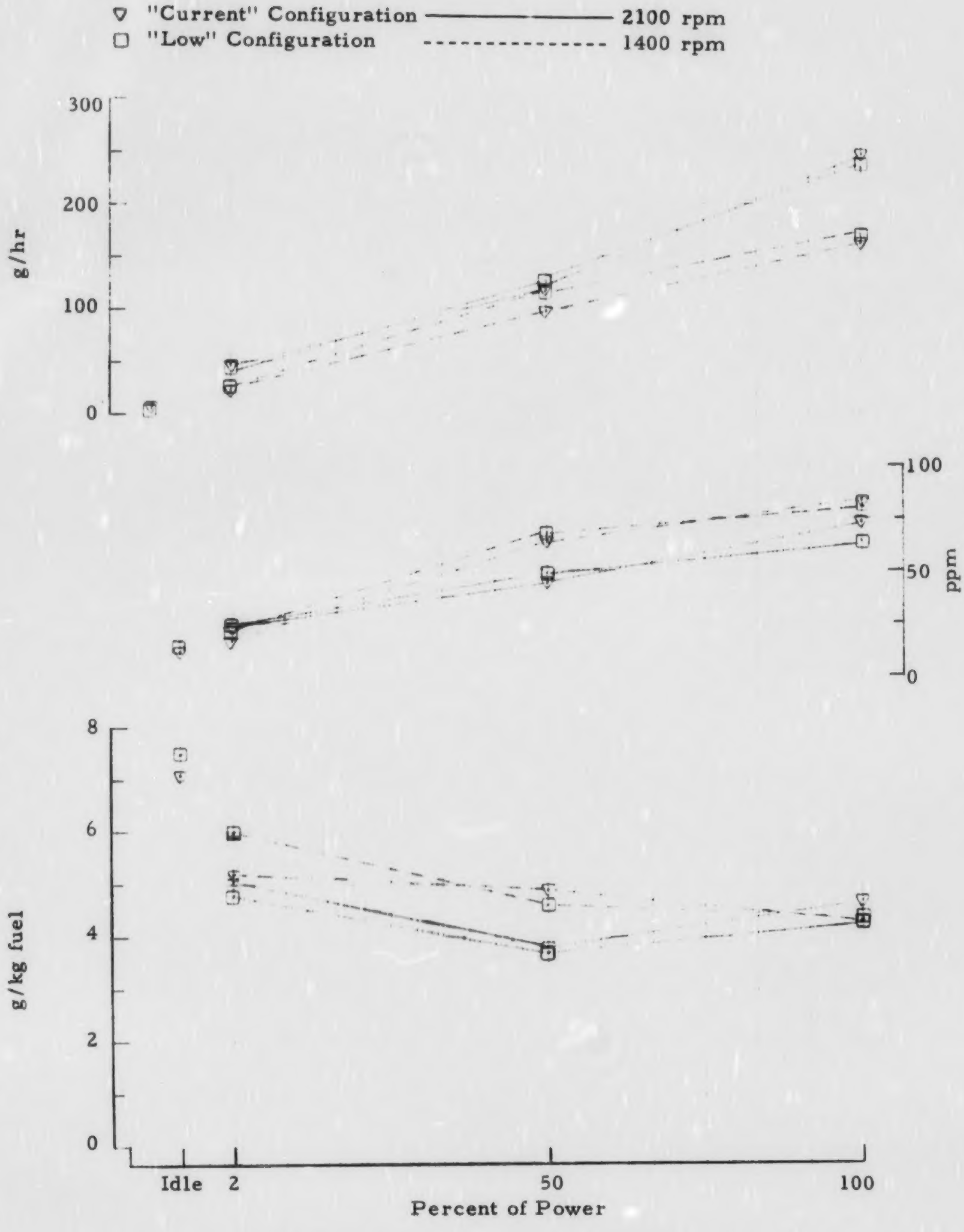


FIGURE 22. $SO_2$ EMISSION RATES FROM CUMMINS NTC-290 TRUCK ENGINE

These same trends followed for the particulate loading in mg/ $m^3$. Sulfate, Figure 21, tended to flatten out between 50 and 100 percent power while $SO_2$ concentrations were quite linear with power. The mass per kg of fuel consumed graphs show that at increasing power, increased fuel rate, particulate decreased as did sulfate and $SO_2$ though the latter decreases are overall trends and are considered slight. Figure 23 is a graph of fuel, power and air flow rates for the seven test conditions with the NTC-290.

### 3. DDAD 8V-71TA

Figures 24, 25 and 26 are the third set of curves depicting the effect of speed and power output on particulate, sulfate and $SO_2$. Particulate and $SO_2$ show an orderly behavior in terms of g/hr, concentration and g/kg fuel. As seen in earlier graphs, the higher the speed, the higher the emission rate in g/hr.

Sulfate, Figure 25, at 100 percent load, 1400 rpm, was a departure from the trend established by the 2100 rpm points. A re-examination of the point in question revealed no problems or mistakes in weighing, sample flow measurement or sulfate analysis. The point was run in duplicate. It is uncertain that the engine could react at one speed one way and at another speed another way, although it is not impossible. Figure 27 is furnished to illustrate the fuel, air, and power behavior of the engine with speed and power level.

### 4. Elemental Analyses

Table 17 is a listing of the percent by weight values for carbon, hydrogen, and sulfur. These analyses were made of the 47 mm glass fiber filters used for particulate gravimetric analysis and mass emission rates per Table 15. One of the duplicate filters was used for determination of carbon and hydrogen. The other filter was used for sulfur analysis.

The most important finding by the carbon and hydrogen values is the obvious difference in hydrogen between the two two-stroke cycle DDAD engines and the four-stroke cycle Cummins NTC-290. The particulate from the four-stroke cycle engine is much lower in hydrogen than the particulate from the two-stroke cycle engines. This is consistent with earlier findings with similar engines.(28) Another interesting though expected finding was the large amount of carbon in presumably elemental form as soot and, to a lesser extent, in organic compounds derived from both fuel and oil.

The percent by weight sulfur levels listed on Table 17 must be viewed with some caution. On a companion project for EPA (Research Triangle Park) the problems of elemental sulfur analysis by ASTM D-1257 have been documented and found to give higher sulfur values with lower sulfur fuels. Comparing the 0.1 percent sulfur fuel used

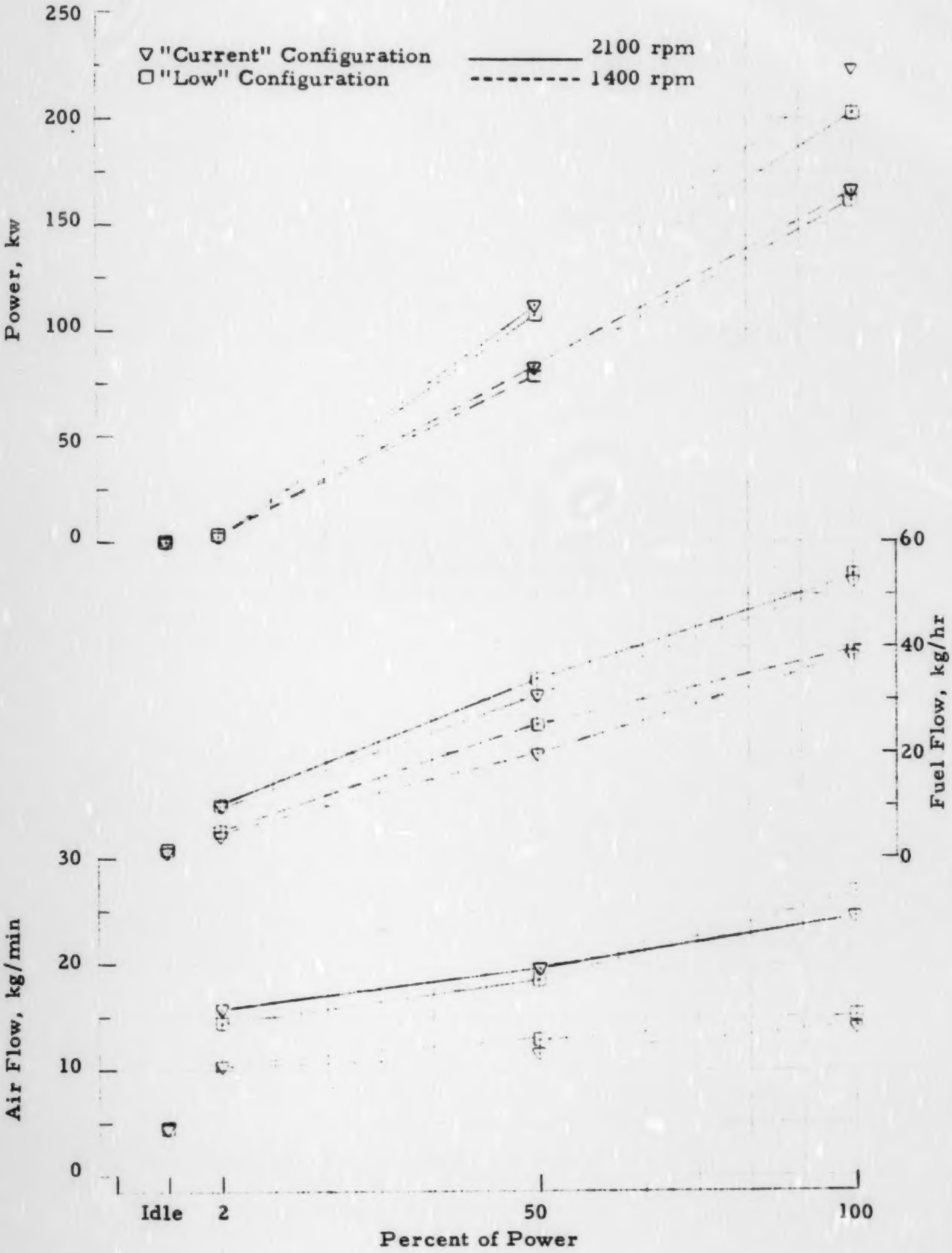


FIGURE 23. POWER OUTPUT FUEL AND AIR RATES FROM CUMMINS NTC 290 TRUCK ENGINE DURING 7 MODE TESTS

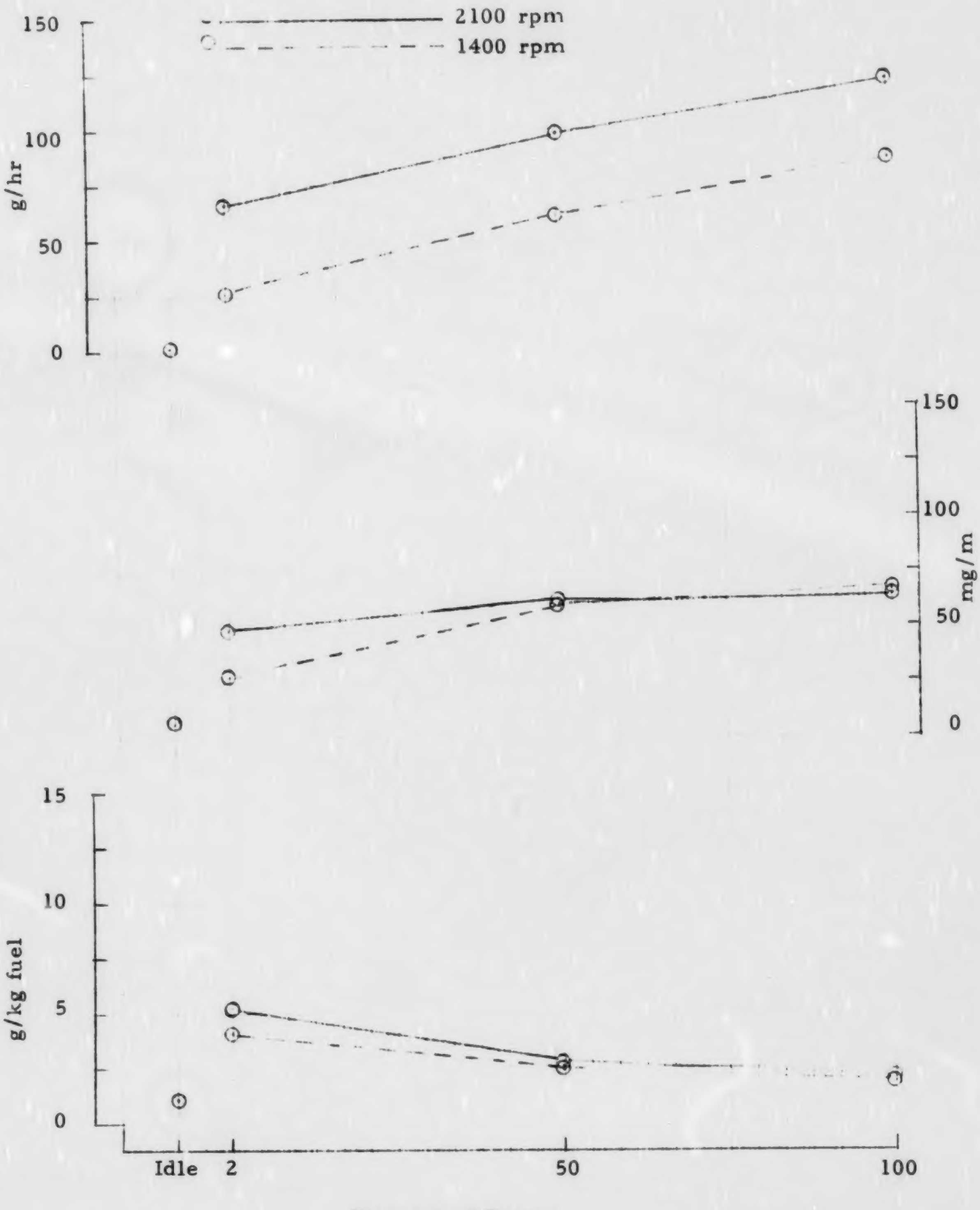


FIGURE 24. PARTICULATE EMISSION RATES FROM DETROIT DIESEL DDAD 8V-71TA TRUCK ENGINE BASED ON 47mm GLASS FILTER

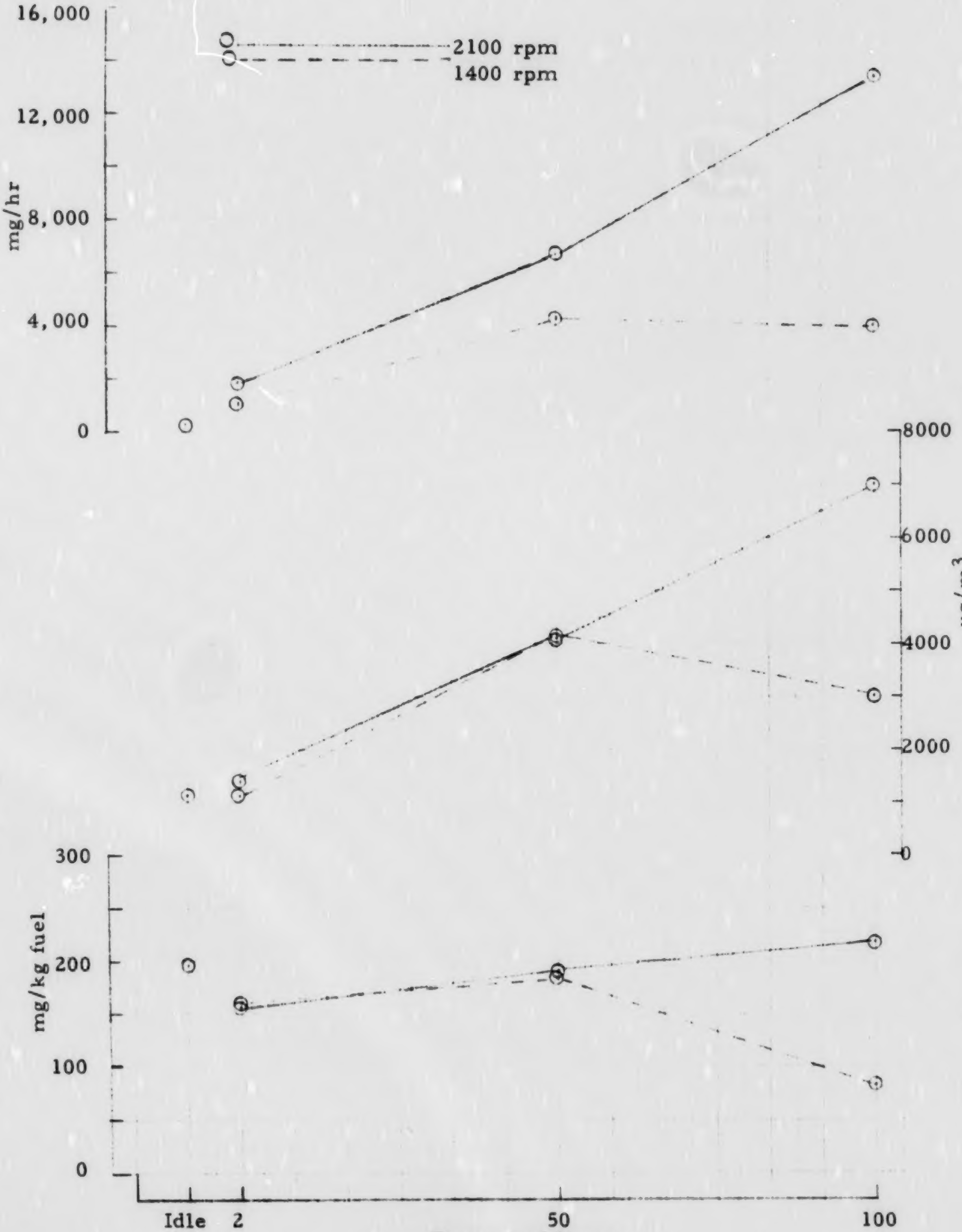


FIGURE 25. SULFATE ($SO_4^=$) EMISSION RATES FROM DETROIT DIESEL DDAD 8V-71TA TRUCK ENGINE BASED ON 47mm FLUOROPORE FILTER

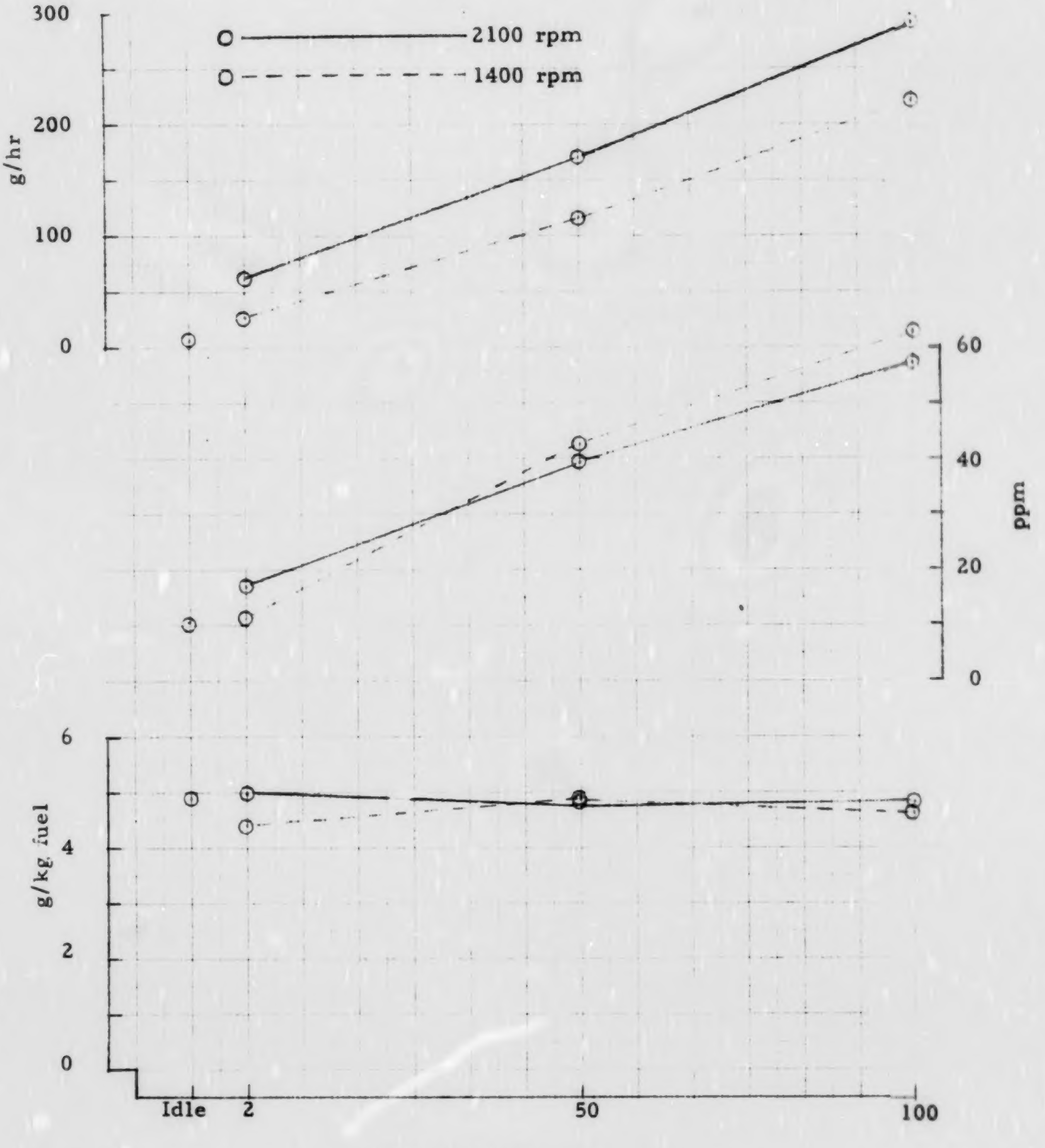


FIGURE 26. $SO_2$ EMISSION RATES FROM DETROIT DIESEL DDAD 8V-71TA TRUCK ENGINE

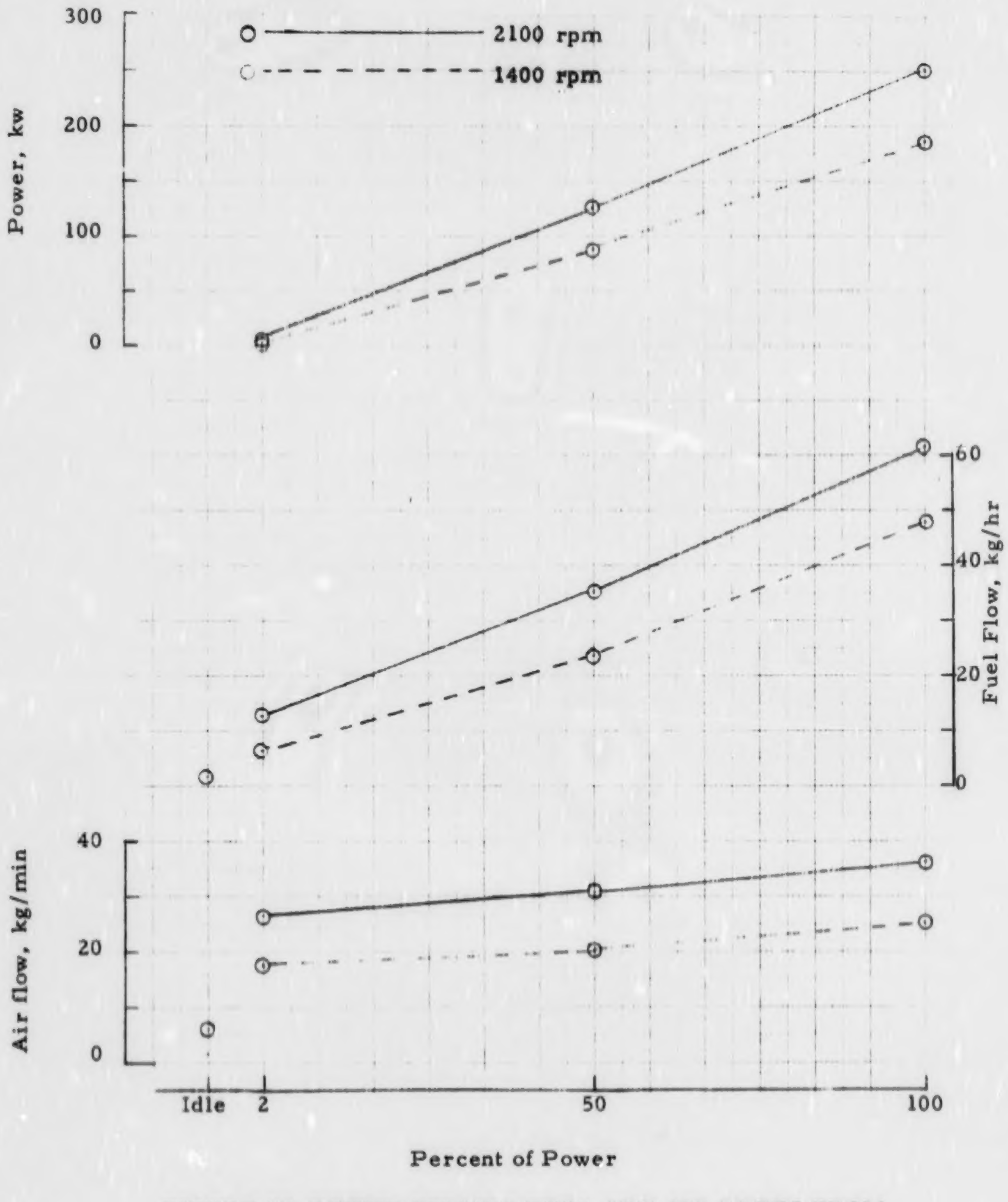


FIGURE 27. POWER OUTPUT FUEL AND AIR RATES FROM DETROIT DIESEL DDAD 8V-71TA TRUCK ENGINE DURING 7-MODE TESTS

### TABLE 17. ELEMENTAL ANALYSES OF FILTER COLLECTED SAMPLES FOR FIVE HD DIESEL ENGINES

| | | Percent by Weight - 47 mm Glass | | | | |
|---|---|---|---|---|---|---|
| | | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
| Condition | Element | LSN 60 | B60E | "Current" | "Low" | 8V-71TA |
| Intermediate Speed, 2% Load | Carbon | 60.18 | 62.25 | 70.88 | 56.16 | 67.19 |
| | Hydrogen | 11.58 | 12.11 | 5.52 | 6.45 | 10.05 |
| | Sulfur | 7.72 | 6.69 | 7.14 | 12.89 | 1.38 |
| Intermediate Speed 50% Load | Carbon | 70.75 | 71.89 | 70.23 | 67.84 | 70.02 |
| | Hydrogen | 13.05 | 12.61 | 2.84 | 1.52 | 8.76 |
| | Sulfur | 3.85 | 3.73 | 3.34 | 1.31 | 1.31 |
| Intermediate Speed, 100% Load | Carbon | 73.10 | 74.96 | 64.12 | 82.10 | 71.72 |
| | Hydrogen | 6.69 | 4.37 | 2.67 | 1.80 | 5.54 |
| | Sulfur | 4.98 | 2.08 | 5.92 | 1.99 | 2.74 |
| Idle Speed, 0 Load | Carbon | 68.69 | 61.90 | 55.11 | 60.99 | 80.41 |
| | Hydrogen | 13.66 | 11.37 | 7.77 | 6.05 | 10.23 |
| | Sulfur | 6.96 | 8.80 | 11.91 | 14.49 | 2.44 |
| High Speed, 100% Load | Carbon | 69.28 | 66.13 | 40.12 | 67.95 | 83.02 |
| | Hydrogen | 12.07 | 9.47 | 4.94 | 2.24 | 6.65 |
| | Sulfur | 4.50 | 5.13 | 4.73 | 5.96 | 1.70 |
| High Speed, 50% Load | Carbon | 79.80 | 71.31 | 69.46 | 78.78 | 67.88 |
| | Hydrogen | 14.22 | 12.97 | 3.32 | 0.37 | 8.49 |
| | Sulfur | 2.85 | 0.93 | 3.64 | 1.87 | 1.54 |
| High Speed, 2% Load | Carbon | 64.48 | 67.74 | 73.74 | 63.03 | 62.85 |
| | Hydrogen | 13.20 | 12.41 | 5.94 | 7.05 | 9.96 |
| | Sulfur | 2.13 | 5.32 | 4.59 | 6.24 | 1.56 |

with the 6V-71 to the results with the 0.23 percent sulfur fuel used with the 8V-71TA, this trend of higher elemental sulfur values is repeated.

Accordingly, the elemental sulfur values are presented as analyzed. It is not known, for example, why under certain test points there is a wide difference, as much as 2:1 between NTC-290 engine configurations. In the time lapse between performing these analyses and publication of this report, a more accurate method has become a standard technique for elemental sulfur. The x-ray fluorescence method widely used for trace metals analysis, has been used successfully for sulfur as well. This analysis normally is made from fluoropore collected samples because of the low background of the plastic media. All future sulfur analyses should be made by the x-ray fluorescence method.

Aside from the mostly qualitative survey of the relative amounts of carbon, hydrogen, and sulfur, the "percent by weight" values may be used directly with the particulate rates already discussed. For example, the mass emission rates for particulate on Table 15 may be multiplied by the decimal equivalent of the appropriate Table 17 percent carbon to obtain an estimation of the mass emission rate of particulate as carbon.

### 5. Discussion

The sulfate and $SO_2$ data presented earlier are the first such results from HD diesel engines using dilution tunnel and the BCA analysis technique. Thus, the data affords a new and clearer insight as to the behavior of the engine and engine variations. The particulate results need little discussion other than the fact that what is collected is considered conservative. Also, it must be mentioned that the method is quite sensitive in that small changes in engine operation or condition are known to give variations in particulate weight. The particulate thus collected, though mostly carbon soot or carbonaceous, does include more or less oil vapor, unburned or partially burned fuel, and sulfuric acid mist.

One way to judge the sulfate measurements is in terms of sulfate as a percent of sulfur in the fuel consumed. Figure 28 is a plot of all five engines, speeds and test points and indicates the variation in conversion efficiency for engine, configuration, speed, and load. The major significance of this graph is the overall average value, and the range of conversions determined. A good average, giving equal weight to all conditions, is about 2.5 percent with 0.9 to 4.5 percent conversion found. This means that for a given fuel sulfur content, it is likely that on the order of 2.5 percent of this sulfur will exit the engine in a form of sulfate as measured by the test technique employed.

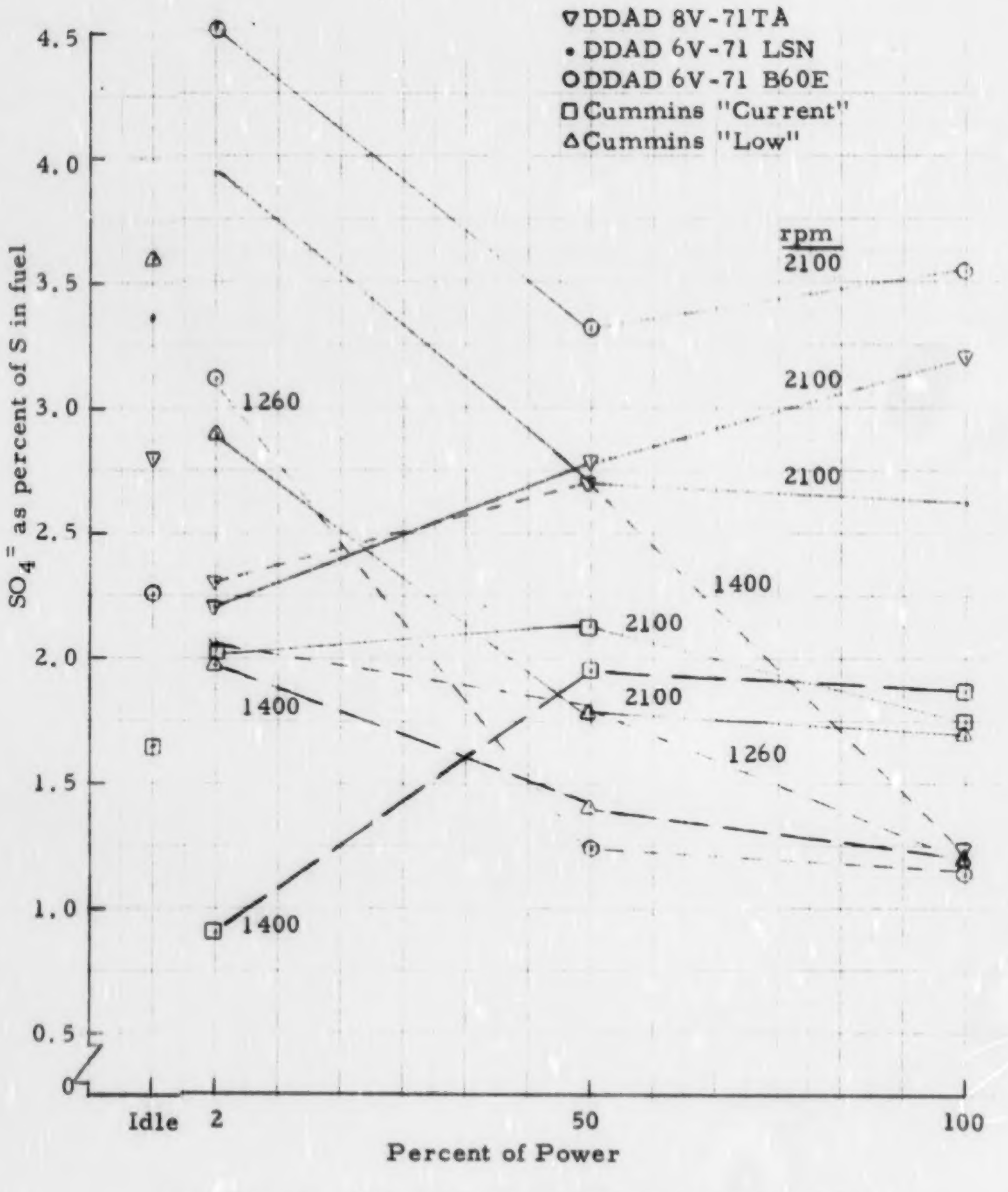


FIGURE 28. SULFATE AS PERCENT OF S IN FUEL FOR VARIOUS HD ENGINE CONFIGURATIONS

Please note that two different fuels, a DF-1 for the city bus engine (6V-71) and a DF-2 for the truck engines (NTC-290 and 8V-71TA), were used. Using $SO_4^=$ as a percent of fuel sulfur makes the results of the five engine study independent of fuel sulfur content. Assuming the diesel engine converts fuel sulfur to sulfate independent of the form or content of sulfur in the fuel is probably not too incorrect an assumption. Then, the values given by these tests could be used in broader estimations of national impact of heavy duty diesel as regards the emission of sulfate or sulfuric acid mist. Other requirements would be engine population and usage, fuel usage and fuel sulfur content for a given diesel engine category.

One final remark concerning sulfur balances of diesel engines. It is clear from the five engine configurations thus studied that on the order of 0.9 to 4.5 percent (general average of 2.5 percent) of the fuel sulfur is converted by the engine to a form measured as sulfuric acid or sulfate. It is also clear from the Table 15 data that $SO_2$ can account for the remainder of the fuel sulfur, at least within the accuracy of the measurements.

With the reality of sulfur balances generally being within ±10 percent and occasionally ±20 percent, then the amount of sulfate is well within the ability to demonstrate recovery in the exhaust. For example, the wet collected - BCA finish for $SO_2$ measurement cannot be considered better than ±10 percent precise. This means that the 2.5 percent sulfate value is within the $SO_2$ accuracy so as to make sulfur balances essentially the same whether sulfate is included or not. In other words, the $SO_2$ measurement is the controlling factor on sulfur balances because it represents essentially 97.5 percent of the value.

From these studies and similar tests with the light duty engines, discussed later, it may be concluded that sulfur balances with most diesel engines have limited value unless equipped with a catalyst. Accordingly, measurement of $SO_2$ is of less importance and could be deleted in most future projects or employed on a selected basis.

## E. Polynuclear Aromatic Hydrocarbons

The results of the 8 x 10 particulate runs, principally for B:ESO and gravimetric analyses, are summarized on Table 18 in terms of concentration, mass per unit of time, per unit of fuel burned and per kw-hr of work performed. Measurements were made specifically for BaP on the last of the five engines thus tested, the DDAD 8V-71TA. Recall from Section III that problems were encountered with the test procedure, as run by Southwest Foundation for Research and Education, making the polynuclear aromatic

## TABLE 18. SUMMARY OF PARTICULATE, BaP AND ORGANIC SOLUBLES FROM 8 x 10 SIZE GLASS FILTER SAMPLES

| Condition | Emission Rate | | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|---|---|
| | | | LSN 60 | B60E | "Current" | "Low" | 8V-71TA* |
| Intermediate Speed, 2% Load | Particulate: | mg/m$^3$ | 24.99 | 30.63 | 16.92 | 16.95 | 31.18 |
| | | g/hr | 17.10 | 20.29 | 8.65 | 8.72 | 27.93 |
| | | g/kg fuel | 4.5 | 5.14 | 1.90 | 1.98 | 4.44 |
| | | g/kw-hr | 9.0 | 10.68 | 2.62 | 2.73 | 7.16 |
| | B:ESO$^{(1)}$ | $\mu$g/m$^3$ | 12.67 | 17.24 | 22.70 | 3.99 | 6.37 |
| | | mg/hr | 8.66 | 11.41 | 1.38 | 2.06 | 5.71 |
| | | mg/kg fuel | 2.[illegible] | 2.89 | 0.303 | 0.467 | 0.921 |
| | | mg/kw-hr | 4.56 | 6.01 | 0.418 | 0.644 | 1.63 |
| | BaP: | $\mu$g/m$^3$ | | | | | 0.417 |
| | | mg/hr | | | | | 0.375 |
| | | mg/kg fuel | | | | | 0.060 |
| | | mg/kw-hr | | | | | 0.107 |
| | Organic Solubles, % of Particulate | | 48.20 | 73.7 | 13.4 | 21.8 | 59.2 |
| Intermediate Speed, 50% Load | Particulate: | mg/m$^3$ | 60.22 | 61.71 | 53.12 | 86.10 | 55.11 |
| | | g/hr | 41.74 | 41.80 | 31.65 | 57.14 | 56.52 |
| | | g/kg fuel | 3.42 | 3.34 | 1.58 | 2.32 | 2.40 |
| | | g/kw-hr | 0.87 | 0.87 | 0.382 | 0.723 | 0.594 |
| | B:ESO$^{(1)}$ | $\mu$g/m$^3$ | 25.94 | 24.97 | 4.75 | 10.80 | 8.38 |
| | | mg/hr | 17.96 | 16.91 | 2.84 | 7.16 | 8.67 |
| | | mg/kg fuel | 1.47 | 1.35 | 0.142 | 0.290 | 0.363 |
| | | mg/kw-hr | 0.37 | 0.351 | 0.0343 | 0.0906 | 0.931 |
| | BaP: | $\mu$g/m$^3$ | | | | | 0.773 |
| | | mg/hr | | | | | 0.796 |
| | | mg/kg fuel | | | | | 0.033 |
| | | mg/kw-hr | | | | | 0.009 |
| | Organic Solubles, % of Particulate | | 76.0 | 76.7 | 7.0 | 3.1 | 51.4 |
| Intermediate Speed, 100% Load | Particulate: | mg/m$^3$ | 59.67 | 94.78 | 40.17 | 85.56 | 66.17 |
| | | g/hr | 42.02 | 63.81 | 29.87 | 67.26 | 87.35 |
| | | g/kg fuel | 1.71 | 2.74 | 0.776 | 1.70 | 1.82 |
| | | g/kw-hr | 0.437 | 0.675 | 0.180 | 0.418 | 0.454 |
| | B:ESO$^{(1)}$ | $\mu$g/m$^3$ | 12.18 | 23.10 | 6.54 | 10.92 | 2.06 |
| | | mg/hr | 8.59 | 15.55 | 4.87 | 8.59 | 2.74 |
| | | mg/kg fuel | 0.349 | 0.667 | 0.126 | 0.217 | 0.057 |
| | | mg/kw-hr | 0.0893 | 0.164 | 0.0294 | 0.0534 | 0.014 |
| | BaP: | $\mu$g/m$^3$ | | | | | 0.446 |
| | | mg/hr | | | | | 0.587 |
| | | mg/kg fuel | | | | | 0.012 |
| | | mg/kw-hr | | | | | 0.003 |
| | Organic Solubles, % of Particulate | | 25.5 | 21.3 | 1.2 | 0.8 | 15.7 |
| Idle Speed, 0 Load | Particulate: | mg/m$^3$ | 31.55 | 20.35 | 40.17 | 12.56 | 13.09 |
| | | g/hr | 6.30 | 4.40 | 2.51 | 2.76 | 3.39 |
| | | g/kg fuel | 6.30 | 4.0 | 2.09 | 1.84 | 2.26 |
| | | g/kw-hr | 0 | 0 | 0 | 0 | 0 |
| | B:ESO$^{(1)}$ | $\mu$g/m$^3$ | 16.79 | 6.87 | 4.23 | 5.49 | 1.69 |
| | | mg/hr | 3.35 | 1.48 | 0.918 | 1.21 | 0.439 |
| | | mg/kg fuel | 3.35 | 1.35 | 0.765 | 0.807 | 0.029 |
| | | mg/kw-hr | 0 | 0 | 0 | 0 | 0 |

## TABLE 18 (Cont'd.) SUMMARY OF PARTICULATE, BaP AND ORGANIC SOLUBLES FROM 8 x 10 SIZE GLASS FILTER SAMPLES

| Condition | Emission Rate | | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|---|---|
| | | | LSN 60 | B60E | "Current" | "Low" | 8V-71TA* |
| | BaP: | $\mu g/m^3$ | | | | | 0.673 |
| | | mg/hr | | | | | 0.175 |
| | | mg/kg fuel | | | | | 0.117 |
| | | mg/kw-hr | | | | | 0 |
| | Organic Solubles, % of Particulate | | 15.7 | 67.2 | 8.8 | 16.3 | 43.2 |
| High Speed, 100% Load | Particulate: | $mg/m^3$ | 104.33 | 127.35 | 24.06 | 48.39 | 48.38 |
| | | g/hr | 116.16 | 136.79 | 30.73 | 67.94 | 94.34 |
| | | g/kg fuel | 3.43 | 4.11 | 0.586 | 1.26 | 1.53 |
| | | g/kw-hr | 0.897 | 1.03 | 0.138 | 0.330 | 0.376 |
| | B:ESO(1) | $\mu g/m^3$ | 12.83 | 31.12 | 3.98 | 5.28 | 4.21 |
| | | mg/hr | 14.29 | 33.45 | 5.09 | 7.42 | 8.26 |
| | | mg/kg fuel | 0.422 | 1.00 | 0.097 | 0.138 | 0.134 |
| | | mg/kw-hr | 0.110 | 0.252 | 0.0227 | 0.0361 | 0.033 |
| | BaP: | $\mu g/m^3$ | | | | | 0.565 |
| | | mg/hr | | | | | 1.111 |
| | | mg/kg fuel | | | | | 0.018 |
| | | mg/kw-hr | | | | | 0.004 |
| | Organic Solubles, % of Particulate | | 54.2 | 47.5 | 14.5 | 3.0 | 58.3 |
| High Speed, 50% Load | Particulate | $mg/m^3$ | 111.10 | 124.56 | 41.20 | 59.23 | [illegible].47 |
| | | g/hr | 123.81 | 134.64 | 42.07 | 67.85 | 9[illegible].54 |
| | | g/kg fuel | 5.92 | 6.68 | 1.39 | 2.00 | 2.57 |
| | | g/kw-hr | 1.82 | 2.03 | 0.377 | 0.637 | 0.719 |
| | B:ESO(1) | $\mu g/m^3$ | 20.19 | 27.70 | 4.54 | 5.38 | 6.52 |
| | | mg/hr | 22.50 | 29.93 | 4.64 | 6.16 | 10.89 |
| | | mg/kg fuel | 1.08 | 1.49 | 0.154 | 0.181 | 0.307 |
| | | mg/kw-hr | 0.331 | 0.451 | 0.0415 | 0.0578 | 0.086 |
| | BaP: | $\mu g/m^3$ | | | | | 1.16 |
| | | mg/hr | | | | | 1.946 |
| | | mg/kg fuel | | | | | 0.055 |
| | | mg/kw-hr | | | | | 0.015 |
| | Organic Solubles, % of Particulate | | 69.6 | 75.0 | 10.7 | 3.3 | 61.1 |
| High Speed, 2% Load | Particulate: | $mg/m^3$ | 81.77 | 87.13 | 29.36 | 40.34 | 43.56 |
| | | g/hr | 90.37 | 93.89 | 23.11 | 32.61 | 59.66 |
| | | g/kg fuel | 10.51 | 10.73 | 2.51 | 3.26 | 4.85 |
| | | g/kw-hr | 34.76 | 34.77 | 5.14 | 7.95 | 11.95 |
| | B:ESO(1) | $\mu g/m^3$ | 27.68 | 19.30 | 3.91 | 5.78 | 11.73 |
| | | mg/hr | 30.59 | 20.79 | 3.09 | 4.67 | 16.14 |
| | | mg/kg fuel | 3.57 | 2.38 | 0.336 | 0.467 | 1.25 |
| | | mg/kw-hr | 11.77 | 7.70 | 0.687 | 1.14 | 3.43 |
| | BaP: | $\mu g/m^3$ | | | | | 1.56 |
| | | mg/hr | | | | | 2.144 |
| | | mg/kg fuel | | | | | 0.166 |
| | | mg/kw-hr | | | | | 0.456 |
| | Organic Solubles, % of Particulate | | 60.3 | 72.2 | 21.9 | 25.2 | 56.9 |

---

(1) Expressed as BaP

*Particulate based on duplicate runs; BaP based on single run hydrocarbon measurements in terms of B:ESO in terms of BaP. BaP is the calibration standard and all measurements are thus expressed as BaP.

Figures 29-31 are plots of the B:ESO results for the three HD engines in terms of mg/hr, $\mu g/m^3$ and mg/kg fuel consumed for the seven points thus evaluated. This being the first such reported data on these particular engines, it is difficult to draw specific comparisons or to comment on the trends indicated.

Some special discussion of the results of the DDAD 8V-71TA engine are in order since both B:ESO and BaP values were obtained on this engine. Table 19 lists the results of both sets of measurements. The ratio of the two is a measure of the correlation or relationship of BaP to the B:ESO.

For example, Table 19 BaP/B:ESO yielded ratios of 0.0725 at 2 percent power-1400 rpm up to 0.3933 at 100 percent power-1400 rpm. Stated differently, BaP was about 7 to 39 percent of the B:ESO for the engine and conditions investigated. The composite 7-mode results for the DDAD 8V-71TA engine showed that BaP/B:ESO to be 0.1375 on a brake specific basis. On a fuel specific basis, the ratio was 0.1388 or in other words, the 7-mode composite BaP represents about 14 percent of the B:ESO.

Attempts were made to analyze the remaining filters from the other two engines without success. The problems were lack of sufficient filters to make additional correlations and the few filters that were available were quite old. Storage stability of the PNA materials is unknown. Therefore, only the B:ESO values are given. To estimate the probable fraction of the B:ESO values listed on Table 18 that is BaP, use the 7 to 39 percent relationship listed on Table 19. In general, multiplication of the B:ESO values by 0.14 will give an estimated level of BaP, as BaP, for the DDAD 6V-71N and, with less confidence, the Cummins NTC-290. It is uncertain whether the 0.14 factor is appropriate for the four-stroke cycle NTC-290 engine.

It is clear that much more work needs to be done on methodology development including sampling, sample preparation and analysis of diesel exhaust PNA content. Such work, beyond the scope of this project, is urgently needed in order to obtain values that have greater precision and are more repeatable and have greater specificity.

Figures 32 through 34 are graphs comparing particulate rates in g/hr, by the 8 x 10 size filter, used for B: ESO and BaP analysis

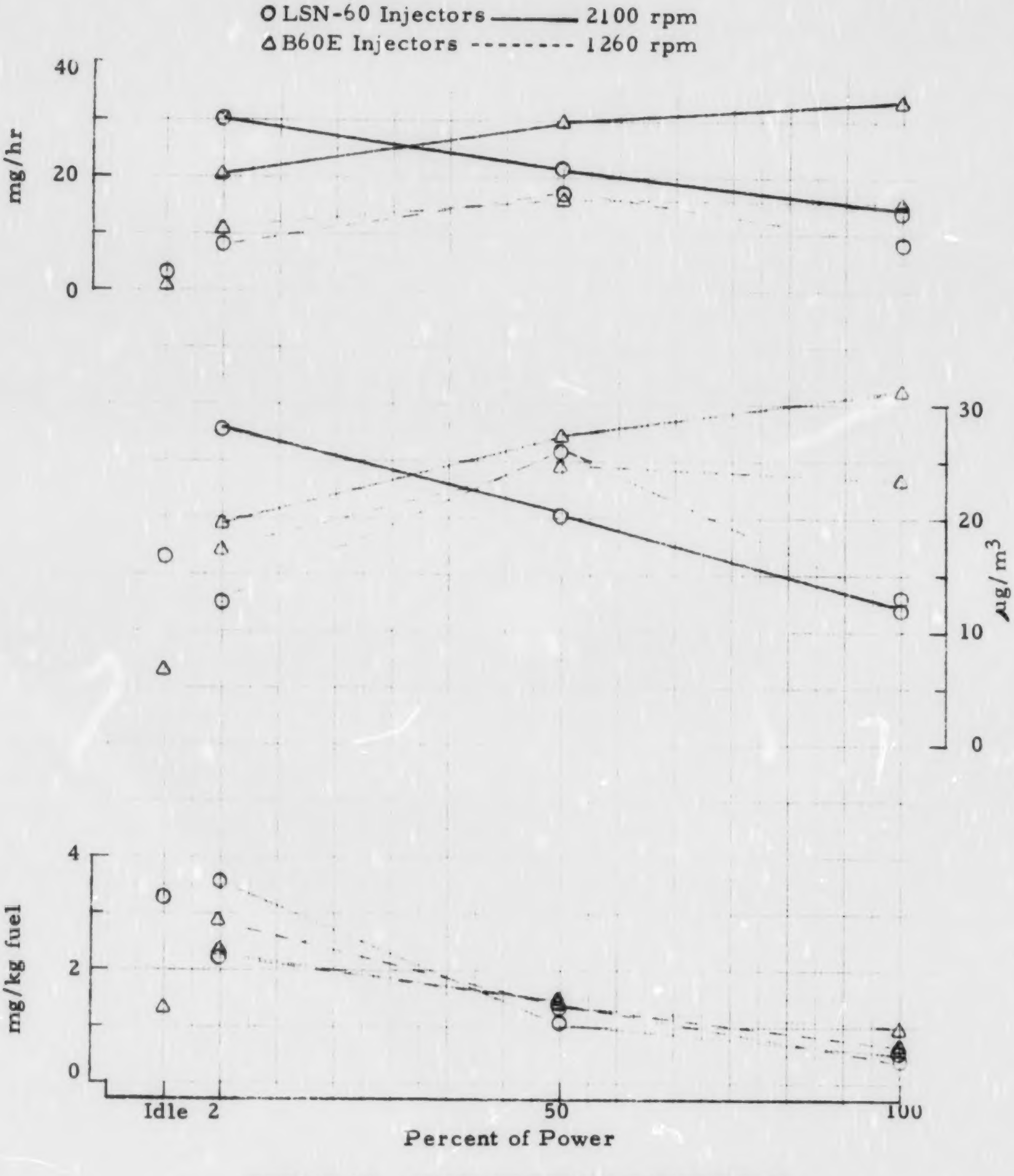


FIGURE 29. B:ESO EMISSION RATES FROM DETROIT DIESEL 6V-71 BUS ENGINE BASED ON 8 x 10 GLASS FILTER

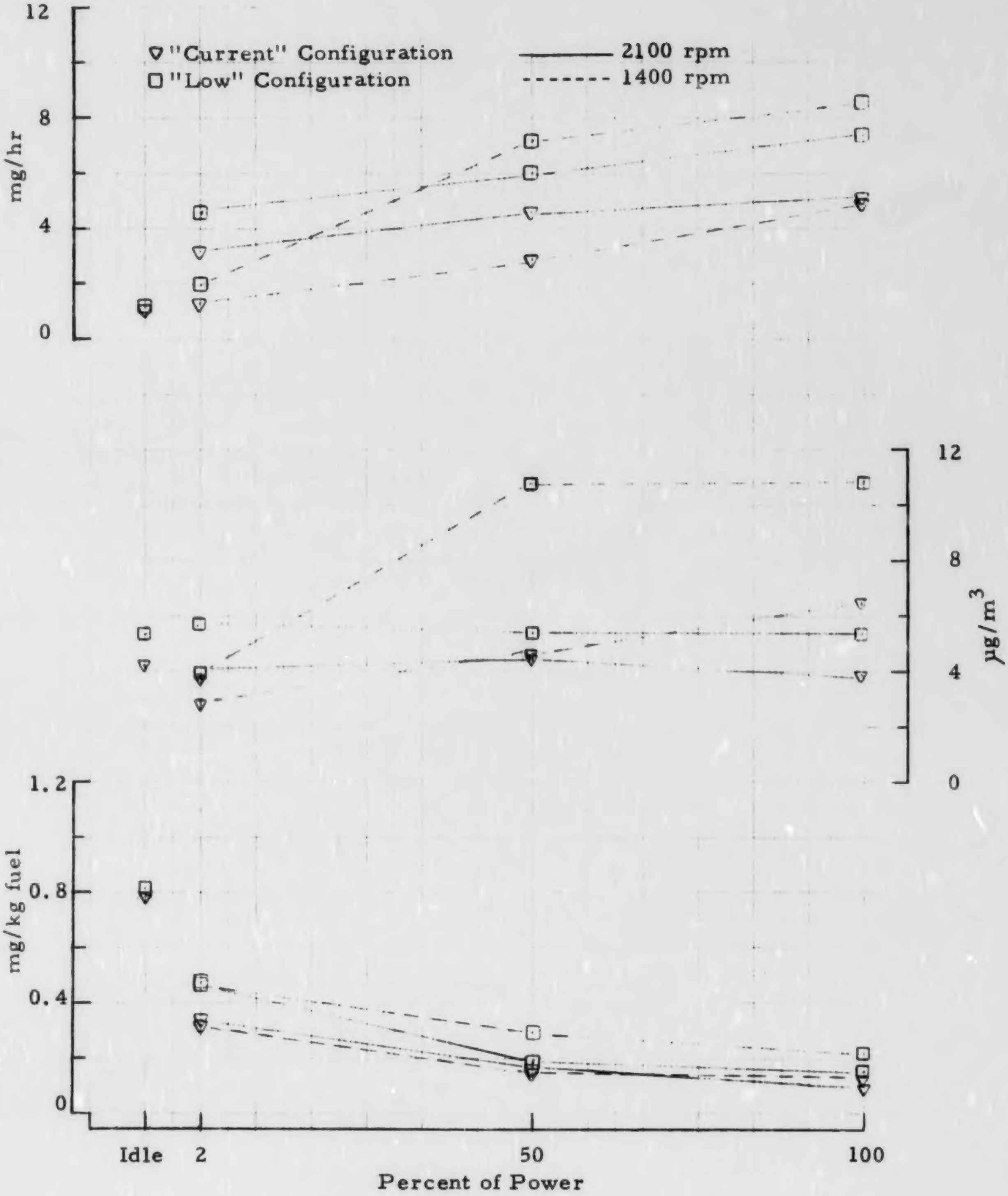


FIGURE 30. B:ESO EMISSION RATES FROM CUMMINS NTC-290 TRUCK ENGINE BASED ON 8 x 10 GLASS FILTER

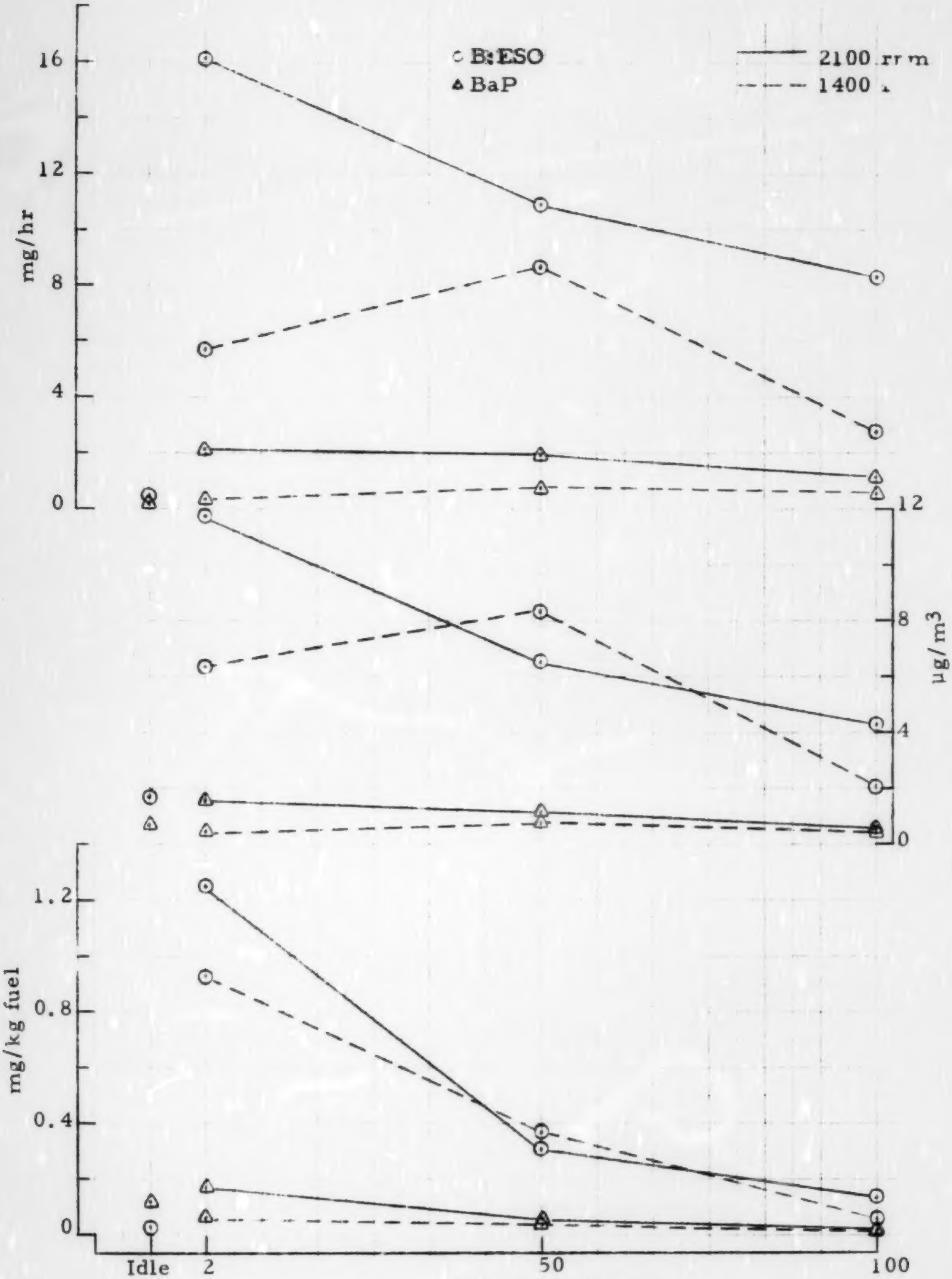


FIGURE 31. B:ESO AND BaP EMISSIONS RATES FROM DETROIT DIESEL 8V-71TA TRUCK ENGINE BASED ON 8 x 10 GLASS FILTERS

TABLE 19. 7-MODE BRAKE AND FUEL SPECIFIC CALCULATIONS - DDAD 8V-71TA

|  |  |  |  |  |  |  |  |  | WEIGHTED |  |  |  |  | Comparison* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mode | % Power | Speed | Fuel kg/hr | Output kw | Wgt. fact | Part g/hr | BaP mg/hr | B:ESO mg/hr | Fuel kg/hr | Power kw | Part g/hr | BaP mg/hr | B:ESO mg/hr | BaP / B:ESO |
| 1 | 2 | 1400 | 6.2 | 3.5 | 0.12 | 26.38 | 0.375 | 5.71 | 0.74 | 0.42 | 3.17 | 0.045 | 0.620 | 0.0725 |
| 2 | 50 | 1400 | 23.9 | 93.1 | 0.16 | 55.78 | 0.796 | 8.67 | 3.82 | 14.89 | 8.92 | 0.127 | 1.387 | 0.0916 |
| 3 | 100 | 1400 | 47.9 | 186.2 | 0.12 | 88.17 | 0.587 | 2.74 | 5.75 | 22.34 | 10.58 | 0.070 | 0.329 | 0.2128 |
| 4 | 0 | 480 | 1.5 | 0.0 | 0.2 | 3.59 | 0.175 | 0.439 | 0.30 | 0.00 | 0.72 | 0.035 | 0.089 | 0.3933 |
| 5 | 100 | 2100 | 61.7 | 252.6 | 0.12 | 93.92 | 1.111 | 8.26 | 7.40 | 30.31 | 11.27 | 0.133 | 0.991 | 0.1342 |
| 6 | 50 | 2100 | 35.5 | 126.3 | 0.16 | 86.67 | 1.946 | 10.89 | 5.68 | 20.21 | 13.87 | 0.311 | 1.742 | 0.1785 |
| 7 | 2 | 2100 | 12.9 | 4.7 | 0.12 | 62.40 | 2.144 | 16.14 | 1.55 | 0.56 | 7.49 | 0.257 | 1.937 | 0.1328 |
|  |  |  |  |  |  |  |  | Totals | 25.24 | 88.73 | 56.02 | 0.978 | 7.10 |  |

BS Particulate $= \frac{\text{g part}}{\text{kw/hr}} = 0.63$

BS BaP $= \frac{\text{mg BaP}}{\text{kw/hr}} = 0.011$

BS B:ESO $= \frac{\text{mg/B:ESO}}{\text{kw/hr}} = 0.080$

FS Particulate $= \frac{\text{g/part}}{\text{kg fuel-hr}} = 2.22$

FS BaP $= \frac{\text{mg/BaP}}{\text{kg/fuel-hr}} = 0.039$

FS B:ESO $= \frac{\text{mg B:ESO}}{\text{kg fuel-hr}} = 0.281$

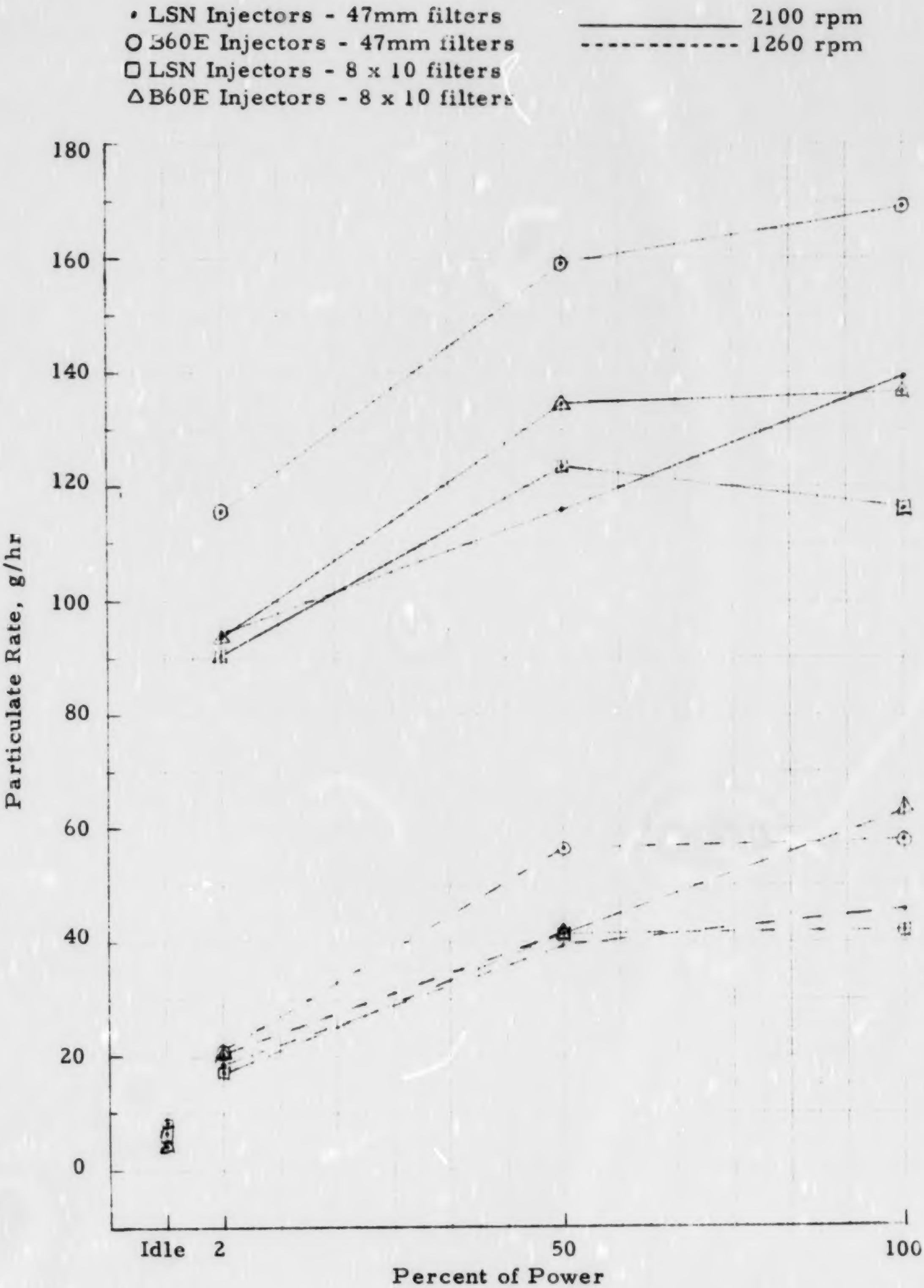


FIGURE 32. COMPARISON OF PARTICULATE g/hr RATES BY 8 x 10 AND 47mm GLASS FILTERS FOR DETROIT DIESEL 6V-71 ENGINE

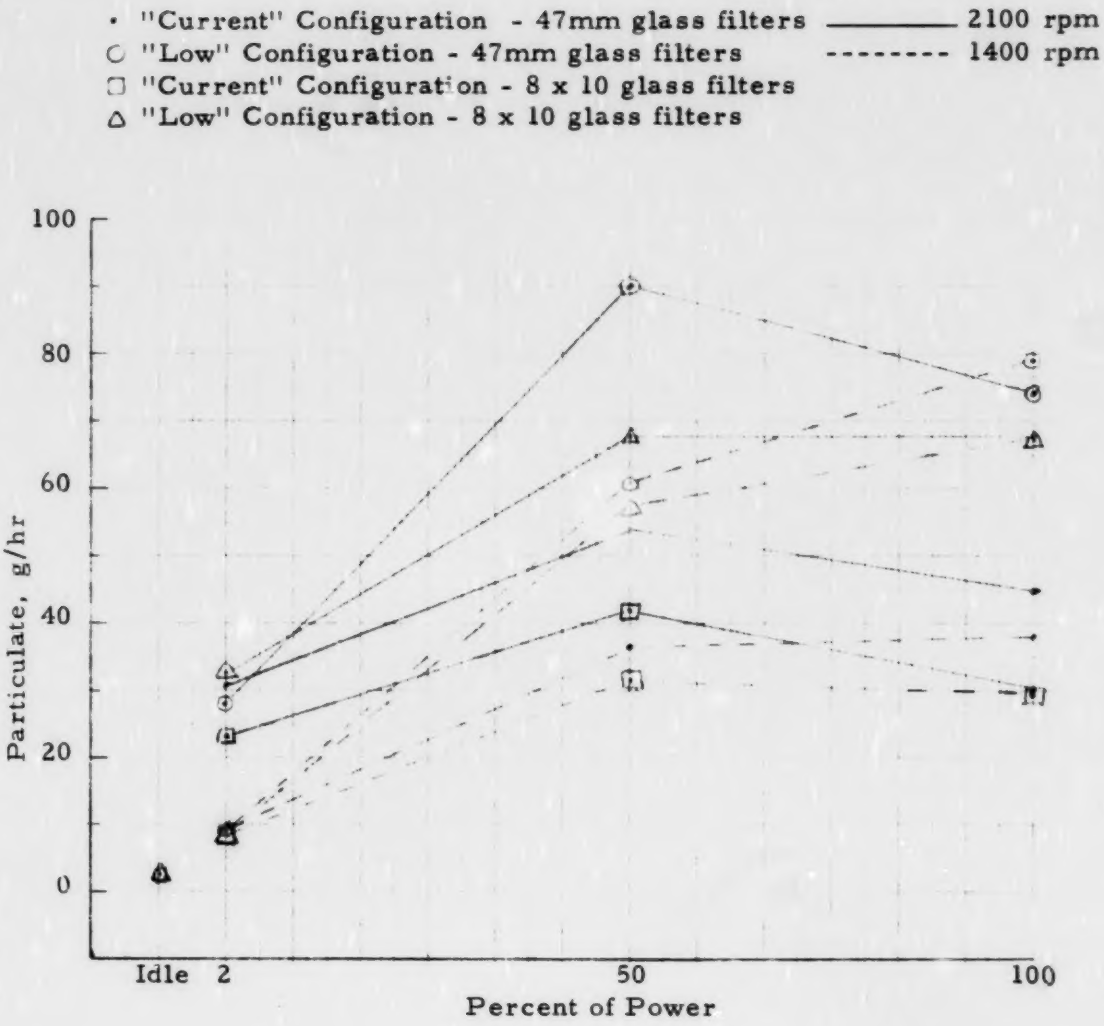


FIGURE 33. COMPARISON OF PARTICULATE g/hr RATES BY 8 x 10 AND 47mm GLASS FILTERS FOR CUMMINS NTC-290 ENGINE

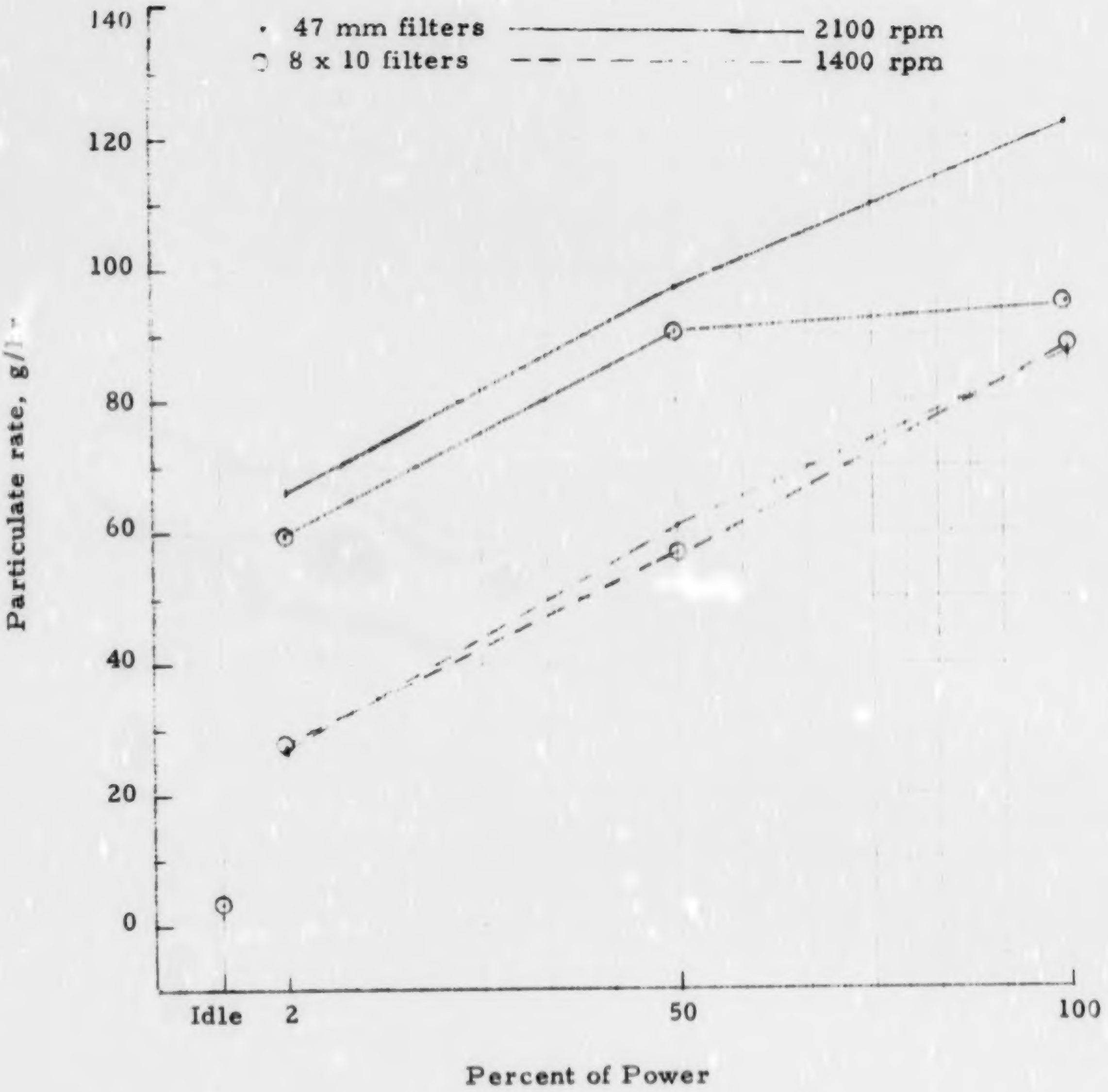


FIGURE 34. COMPARISON OF PARTICULATE g/hr RATES BY 8 x 10 AND 47 mm GLASS FILTERS FOR DETROIT DIESEL 8V-71TA

with the 47 mm glass fiber filters used for particulate rate and discussed earlier. The comparison is quite reasonable and satisfactory of the particulate rates by the two somewhat different methods. The level of agreement shown helps to confirm this aspect of the large size filters since particulate rate is involved in the B:ESO and BaP emission rate computations.

Table 20 is a summary listing of the engine operating parameters experienced during the 8 x 10 inch glass fiber filter, 7-mode runs. The operating data for the 8 x 10 runs is essentially a repeat of the 4 x 47 mm filter runs described on Table 15.

## F. Discussion and Summary

One way to discuss and summarize the emissions evaluation of the five HD diesel engine configurations is to compute a combined emission rate from the seven-mode data using weighting factors derived from the 13-mode emissions test. Table 21 is a summary of the composite emission rates for sulfate, $SO_2$, particulate and B:ESO, four of the principal non-regulated pollutants. Both brake and fuel specific rates are given.

The specific weighting factors and supporting rationale for their selection was described in Section III. Briefly, the rationale used was the 2 percent (and 100 percent) load points would cover half of the time or operation usually accounted for by the 25 percent (and 75 percent) load points of the 13-mode test. Thus, the change in the 2 percent (and 100 percent) load weight factors up to only 0.12 from 0.08. Note that the 50 percent load factor was doubled to 0.16 from 0.08 to account for the other half of the 25 and 75 percent load points not accounted for by the 2 and 100 percent load factors.

The approximation of the "13 mode" really then depends on how well the 3 modes at each speed agree with the trend of the usual 5 modes at each speed. If the 13 mode data can be considered linear, then the approximation is considered valid. Note that the use of just 5 modes per speed in the 13 mode test is based to some extent on this argument of smooth or continuous emission behavior as a function of power output, which is fairly valid. The 7-mode test is therefore considered to be an adequate map for purposes of this characterization and represents the best compromise of modal data for the level of effort available.

Please recall that the Detroit Diesel 6V-71 engine was operated on a 0.1 percent S fuel (DF-1 national average) and the Detroit Diesel 8V-71TA and Cummins on a 0.23 percent S fuel (DF-2 national average). Thus, the g/kw-hr $SO_2$ and $SO_4^=$ values for the Cummins and DDAD 8V-71TA on Figure 36 are expected to be higher than the Detroit 6V-71 values.

## TABLE 20. SUMMARY OF ENGINE OPERATING CONDITIONS DURING 8 x 10 SIZE GLASS FILTER TESTS

| | | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|---|
| Condition | Engine Operation | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| Intermediate Speed, 2% Load | Engine Speed, rpm | 1260 | 1260 | 1400 | 1400 | 1400 |
| | Power Output, kw | 1.9 | 1.9 | 3.3 | 3.2 | 3.5 |
| | Fuel Rate, kg/hr | 3.8 | 4.0 | 4.5 | 4.4 | 6.2 |
| | Air Rate, kg/min | 13.5 | 13.1 | 10.2 | 10.2 | 17.5 |
| | BSFC kg/kw-hr | 1.989 | 2.105 | 1.352 | 1.363 | 1.666 |
| | Inlet Temp, °C | 26.1 | 23.3 | 31.1 | 28.3 | 22.7 |
| | Inlet Rest., mm Hg | 21.5 | 20.2 | 11.2 | 8.8 | 14.0 |
| | Exh. Rest., mm Hg | 50.8 | 50.8 | 20.3 | 15.2 | 30.5 |
| Intermediate Speed 50% Load | Engine Speed, rpm | 1260 | 1260 | 1400 | 1400 | 1400 |
| | Power Output, kw | 48.2 | 48.2 | 82.8 | 79.0 | 93.1 |
| | Fuel Rate, kg/hr | 12.2 | 12.5 | 20.0 | 24.7 | 23.9 |
| | Air Rate, kg/min | 14.9 | 13.2 | 11.5 | 12.9 | 20.3 |
| | BSFC, kg/kw-hr | 0.253 | 0.259 | 0.242 | 0.312 | 0.256 |
| | Inlet Temp. °C | 27.2 | 31.7 | 28.3 | 28.3 | 23.4 |
| | Inlet Rest., mm Hg | 21.7 | 20.9 | 13.4 | 13.5 | 16.8 |
| | Exh. Rest., mm Hg | 63.5 | 63.5 | 27.9 | 27.9 | 40.6 |
| Intermediate Speed 100% Load | Engine Speed, rpm | 1260 | 1260 | 1400 | 1400 | 1400 |
| | Power Output, kw | 96.2 | 94.6 | 165.7 | 160.8 | 186.2 |
| | Fuel Rate, kg/hr | 24.6 | 23.3 | 38.5 | 39.6 | 47.9 |
| | Air Rate, kg/min | 13.5 | 13.2 | 14.3 | 15.1 | 25.3 |
| | BSFC kg/kw-hr | 0.256 | 0.246 | 0.233 | 0.246 | 0.257 |
| | Inlet Temp. °C | 29.4 | 31.7 | 28.9 | 32.8 | 24.6 |
| | Inlet Rest., mm Hg | 22.0 | 19.8 | 19.1 | 17.7 | 25.2 |
| | Exh. Rest., mm Hg | 78.5 | 76.2 | 27.9 | 30.5 | 50.8 |
| Idle Speed 0% Load | Engine Speed, rpm | 430 | 430 | 615 | 615 | 480 |
| | Power Output, kw | 0 | 0 | 0 | 0 | 0 |
| | Fuel Rate, kg/hr | 0.97 | 1.1 | 1.23 | 1.52 | 1.5 |
| | Air Rate, kg/min | 4.0 | 4.3 | 4.3 | 4.4 | 6.2 |
| | BSFC kg/kw-hr | ---- | ---- | ---- | ---- | ---- |
| | Inlet Temp, °C | 17.2 | 26.1 | 28.9 | 32.2 | 22.8 |
| | Inlet Rest., mm Hg | 3.9 | 3.2 | 2.8 | 2.2 | 2.8 |
| | Exh. Rest., mm Hg | 24.4 | 25.4 | 14.2 | 15.2 | 25.4 |
| High Speed 100% | Engine Speed, rpm | 2100 | 2100 | 2100 | 2100 | |
| | Power Output, kw | 129.5 | 132.6 | 223.4 | 205.7 | 252.6 |
| | Fuel Rate, kg/hr | 33.9 | 33.3 | 52.4 | 53.76 | 61.7 |
| | Air Rate, kg/min | 21.6 | 20.6 | 24.5 | 26.8 | 36.2 |
| | BSFC kg/kw-hr | 0.262 | 0.251 | 0.235 | 0.261 | 0.244 |
| | Inlet Temp. °C | 31.1 | 34.4 | 30.6 | 32.8 | 25.0 |
| | Inlet Rest., mm Hg | 46.9 | 46.0 | 49.3 | 46.0 | 49.5 |
| | Exh. Rest., mm Hg | 101.5 | 101.6 | 48.8 | 58.4 | 88.9 |

## TABLE 20. SUMMARY OF ENGINE OPERATING CONDITIONS DURING 8 x 10 SIZE GLASS FILTER TESTS (CONT'D.)

| Condition | Engine Operation | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|---|
| | | LSN 60 | B 60 E | "Current" | "Low" | 8V-71TA |
| High Speed 50% Load | Engine Speed, rpm | 2100 | 2100 | 2100 | 2100 | 2100 |
| | Power Output, kw | 67.9 | 66.3 | 111.7 | 106.5 | 126.3 |
| | Fuel Rate, kg/hr | 20.9 | 20.2 | 30.2 | 33.9 | 35.5 |
| | Air Rate, kg/min | 21.8 | 21.1 | 15.5 | 22.4 | 30.8 |
| | BSFC kg/kw-hr | 0.308 | 0.305 | 0.270 | 0.318 | 0.281 |
| | Inlet Temp, °C | 31.7 | 30.6 | 29.4 | 30.0 | 25.7 |
| | Inlet Rest., mm $H_2$ | 47.6 | 47.3 | 33.3 | 32.1 | 37.4 |
| | Exh. Rest., mm Hg | 90.2 | 88.9 | 30.2 | 38.1 | 63.5 |
| High Speed 2% Load | Engine Speed, rpm | 2100 | 2100 | 2100 | 2100 | 2100 |
| | Power Output, kw | 2.6 | 2.7 | 4.5 | 4.1 | 4.7 |
| | Fuel Rate, kg/hr | 8.6 | 8.75 | 9.23 | 10.0 | 12.9 |
| | Air Rate, kg/min | 21.8 | 21.2 | 19.9 | 15.9 | 26.8 |
| | BSFC kg/kw-hr | 3.308 | 3.240 | 2.051 | 2.439 | 2.744 |
| | Inlet Temp, °C | 31.1 | 29.4 | 29.4 | 27.8 | 23.3 |
| | Inlet Rest., mm Hg | 48.4 | 47.3 | 22.0 | 19.1 | 27.0 |
| | Exh. Rest., mm Hg | 75.2 | 76.2 | 27.7 | 27.9 | 38.1 |

## TABLE 21. BRAKE AND FUEL SPECIFIC EMISSION RATES OF FIVE HEAVY DUTY DIESEL ENGINE CONFIGURATIONS

| | DDAD 6V-71 | | Cummins NTC-290 | | DDAD |
|---|---|---|---|---|---|
| Emission Rate | LSN-60 | B 60 E | "Current" | "Low" | 8V-71TA |
| Brake Specific Based on 7-Mode Schedule | | | | | |
| Particulate, g/kw-hr (47 mm glass filter) | 1.90 | 1.74 | 0.381 | 0.671 | 0.697 |
| Particulate, g/kw-hr (8 x 10 glass filter) | 1.29 | 1.45 | 0.297 | 0.540 | 0.63 |
| Sulfate, mg/kw-hr | 21.16 | 25.22 | 35.02 | 37.26 | 48.37 |
| $H_2SO_4$, mg/kw-hr | 21.60 | 25.75 | 35.76 | 38.04 | 49.39 |
| $SO_2$, g/kw-hr | 0.584 | 0.590 | 1.19 | 1.38 | 1.35 |
| B:ESO, mg/kw-hr(1) | 0.316 | 0.380 | 0.0395 | 0.066 | 0.080 |
| BaP, mg/kw-hr | | | | | 0.011 |
| Brake Specific Based on 13-Mode Schedule | | | | | |
| CO, g/kw-hr | 7.50 | 4.65 | 1.99 | 2.43 | 3.65 |
| HC, g/kw-hr | 2.77 | 1.30 | 0.38 | 0.84 | 0.96 |
| NO as $NO_2$, g/kw-hr | 17.19 | 11.79 | 15.09 | 6.74 | 10.86 |
| HC+$NO_2$, g/kw-hr | 19.96 | 13.09 | 15.46 | 7.58 | 11.84 |
| Fuel Specific Based on 7-Mode Schedule | | | | | |
| Particulate, g/kg fuel (47 mm glass filter) | 4.43 | 5.75 | 1.44 | 2.09 | 2.45 |
| Particulate, g/kg fuel (8 x 10 glass filter) | 4.26 | 4.86 | 1.12 | 1.85 | 2.22 |
| Sulfate, mg/kg fuel | 70.87 | 83.28 | 131.89 | 116.30 | 170.06 |
| $H_2SO_4$, mg/kg fuel | 72.36 | 85.03 | 134.66 | 118.74 | 173.63 |
| $SO_2$, g/kg fuel | 1.96 | 1.95 | 4.49 | 4.31 | 4.76 |
| B:ESO, mg/kg fuel(1) | 1.04 | 1.27 | 0.149 | 0.226 | 0.281 |
| BaP, mg/kg fuel | | | | | 0.039 |
| Fuel Specific Based on 13-Mode Schedule | | | | | |
| CO, g/kg fuel | 26.41 | 16.09 | 7.34 | 8.41 | 12.5 |
| HC, g/kg fuel | 9.75 | 4.50 | 1.40 | 2.91 | 3.29 |
| NO as $NO_2$, g/kg fuel | 60.53 | 40.80 | 55.68 | 23.32 | 37.19 |
| HC+$NO_2$, g/kg fuel | 70.28 | 45.29 | 57.05 | 26.23 | 40.55 |
| Brake Specific Fuel Consumption Based on 13-Mode Schedule | | | | | |
| BSFC, kg fuel/kw-hr | 0.284 | 0.289 | 0.271 | 0.289 | 0.292 |

---

(1) B:ESO in terms of BaP

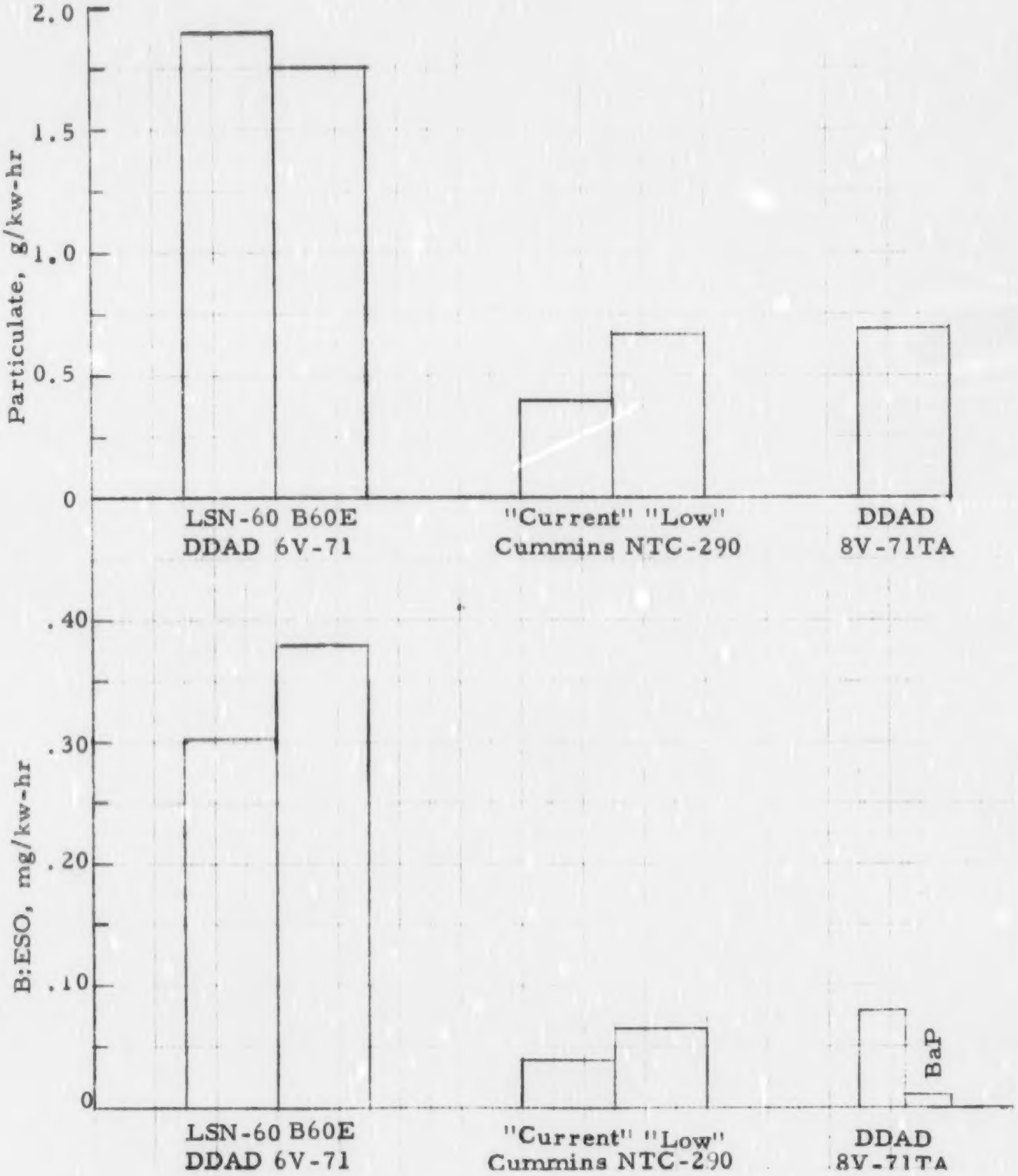


FIGURE 35. BRAKE SPECIFIC B:ESO, BaP AND PARTICULATE FROM FIVE HEAVY DUTY DIESEL ENGINE CONFIGURATIONS
(7 Mode Schedule)

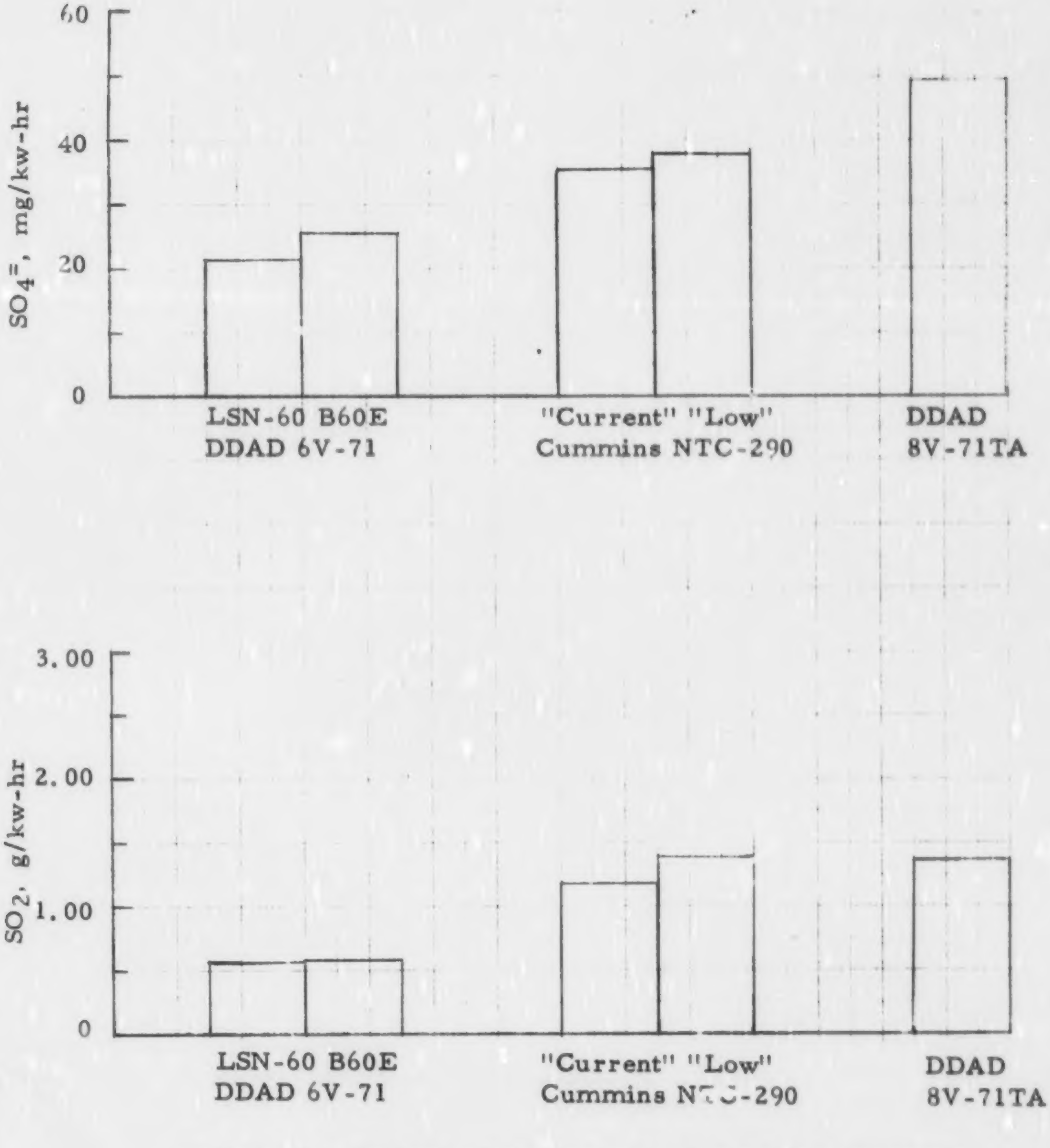


FIGURE 36. BRAKE SPECIFIC $SO_2$ AND $SO_4^=$ EMISSIONS FROM FIVE HEAVY DUTY DIESEL ENGINE CONFIGURATIONS
(7 Mode Schedule)

For completeness, the 13-mode FTP brake specific values are bar graphed in Figures 37 and 38 in terms of CO, NO and $NO_2$, HC and $HC+NO_x$. These data were reported earlier in this report. There are many areas of interest indicated by the extensive data summaries thus far presented. Many questions can be asked as to why or how did $SO_4^=$, B:ESO and BaP, particulate and gaseous emissions react as they did to engine, fuel, injector type, timing, speed, load, etc. The answers to these questions, beyond engineering judgment, are not within the scope of work of this project.

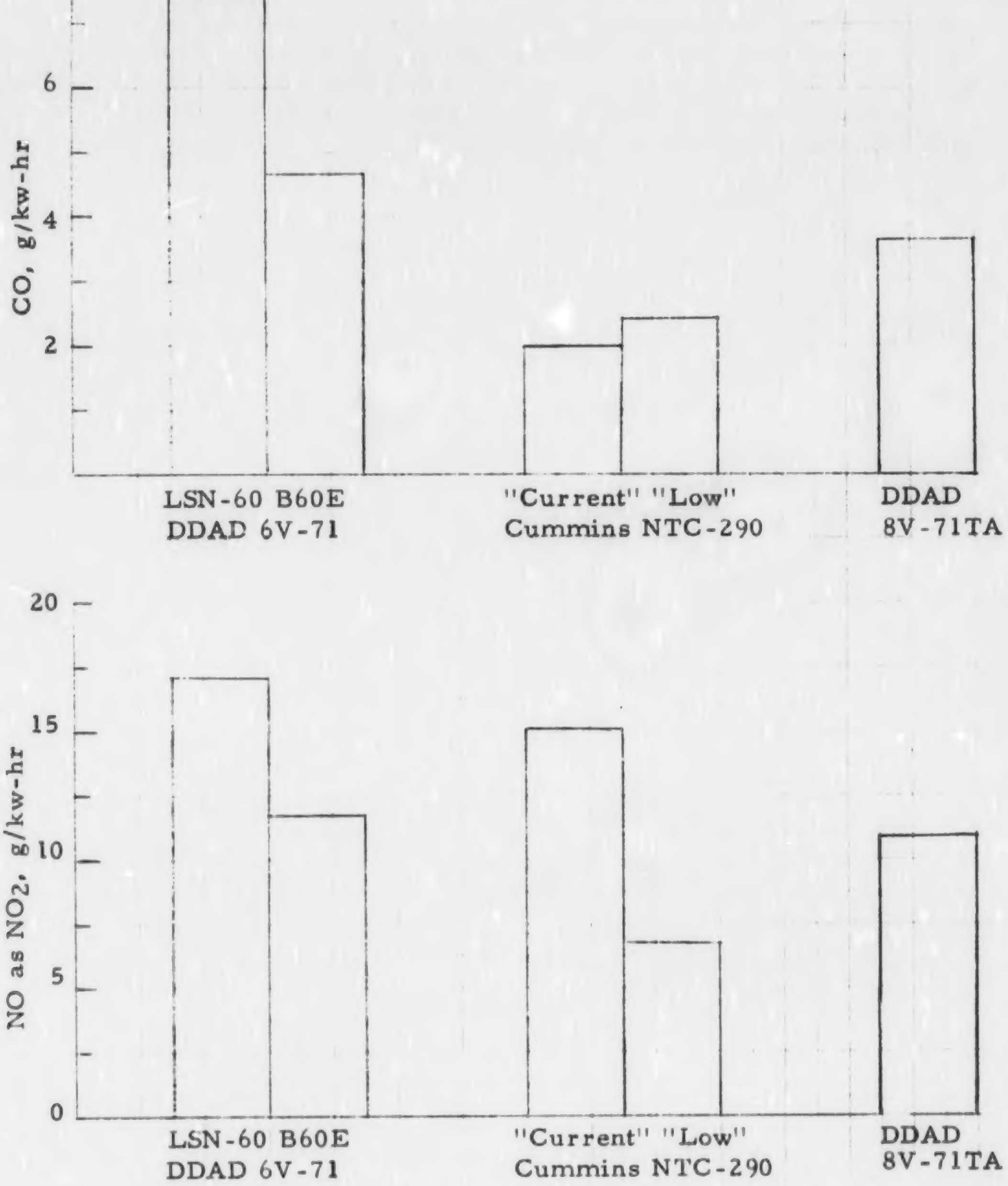


FIGURE 37. BRAKE SPECIFIC CO AND NO AS $NO_2$ EMISSIONS FROM FIVE HEAVY DUTY DIESEL ENGINE CONFIGURATIONS (13 Mode FTP)

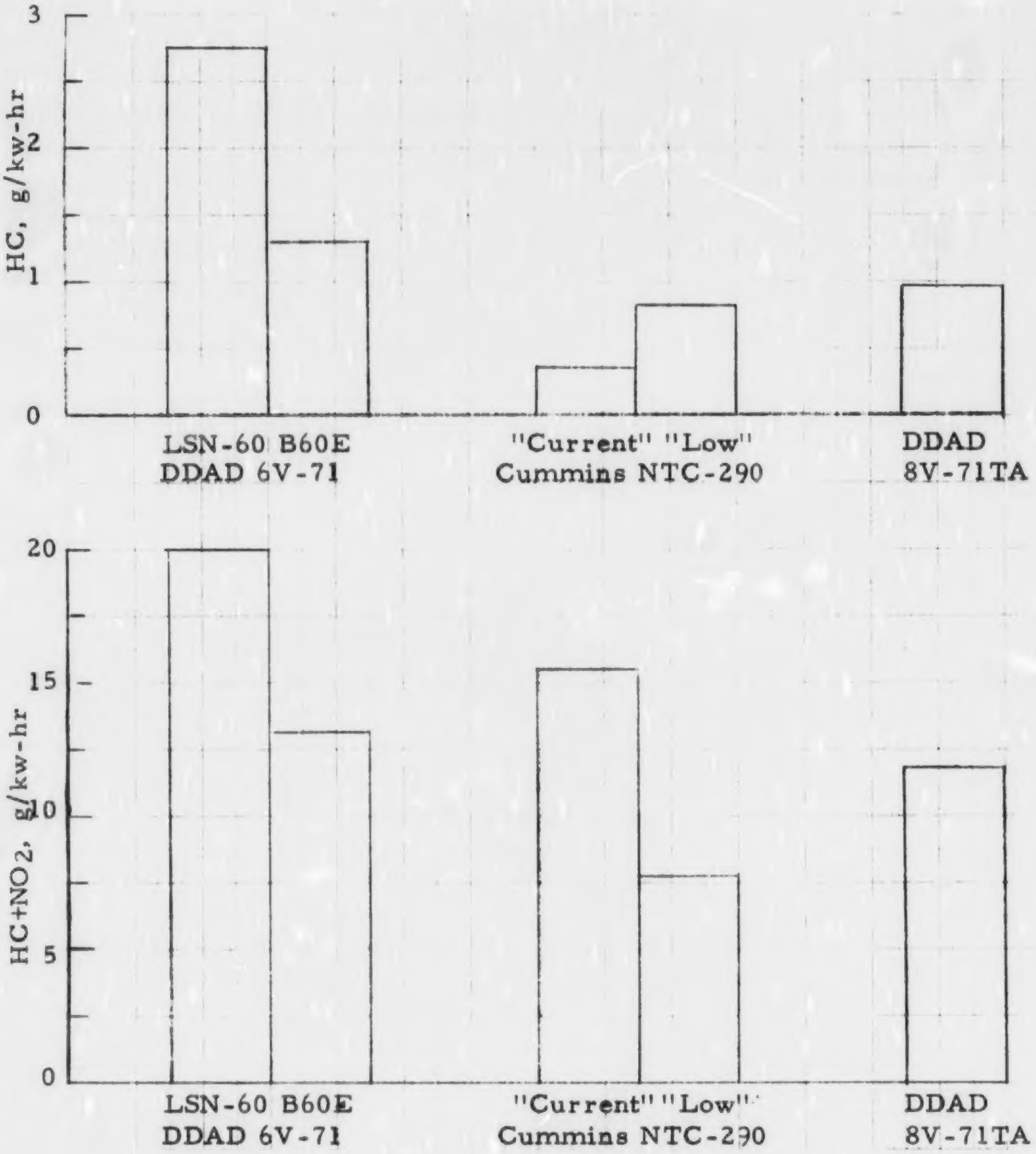


FIGURE 38. BRAKE SPECIFIC HC AND HC+$NO_2$ EMISSIONS FROM FIVE HEAVY DUTY DIESEL ENGINE CONFIGURATIONS (13 Mode FTP)

## V. RESULTS OF FIVE DIESEL POWERED LIGHT DUTY VEHICLES

The results of the five light duty diesel powered vehicles are described by emission category. For description of test methods, procedures and equipment, please refer to Section III.

### A. Regulated Emissions and Fuel Economy

The transient test procedures known as the FTP, SET and FET were the basis for measurement of gaseous emissions of HC, CO and $NO_x$ as well as fuel economy.

#### 1. Emission Standards

The contractural requirement to report all data and results in modernized metric units (SI) requires a statement of equivalent emission standards for 1973 and later model year light duty cars in grams per kilometer (g/km) for understanding. Table 22 lists the HC, CO and $NO_x$ limits in g/km with those published in appropriate Federal Registers in g/mile in parentheses. The conversion was based on 1.609 km equal to 1 mile and were rounded to the same number of decimals as the published limit. The metric equivalent levels are approximately 62 percent of the mixed metric-English units.

TABLE 22. FEDERAL LIGHT DUTY EMISSION STANDARDS

| Year | Units | HC | CO | $NO_x$ |
|---|---|---|---|---|
| 1973-1974 | g/km | 2.1 | 24 | 1.9 |
| | (g/mile) | (3.4) | (39) | (3.0) |
| 1975 Interim | g/km | 0.9 | 9.3 | 1.9 |
| | (g/mile) | (1.5) | (15) | (3.1) |
| Original | g/km | 0.25 | 2.1 | 1.9 |
| 1975 Statutory | (g/mile) | (0.41) | (3.4) | (3.1) |
| 1977 Statutory | g/km | 0.25 | 2.1 | 1.3 |
| | (g/mile) | (0.41) | (3.4) | (2.0) |
| 1978 Statutory | g/km | 0.25 | 2.1 | 0.25 |
| | (g/mile) | (0.41) | (3.4) | (0.40) |

#### 2. Emissions and Fuel Economy

Table 23 is a summary of the gaseous emissions of HC, CO and $NO_x$ (in g/km), fuel consumption (in l/100 km) and the reciprocal of fuel consumption, fuel economy in mpg. Of most importance on Table 23 are

## TABLE 23. HC, CO, $NO_x$ AND FUEL RESULTS FIVE DIESEL LDV's (Average of Replicate Runs)

| Test | Vehicle | Emissions, g/km | | | Fuel Cons. | Fuel Econ. |
|---|---|---|---|---|---|---|
| | | HC | CO | $NO_x$ | 1/100 km | mpg |
| 1975 FTP | Mercedes 220D* | 0.11 | 0.81 | 0.65 | 9.10 | 25.92 |
| | Mercedes 240D | 0.18 | 0.60 | 0.79 | 9.15 | 25.72 |
| | Mercedes 300D | 0.10 | 0.53 | 1.07 | 9.90 | 23.80 |
| | Peugeot 204D | 0.69 | 1.06 | 0.42 | 6.72 | 35.86 |
| | Perkins 6-247 | 0.45 | 1.78 | 0.93 | 9.18 | 25.67 |
| | Average | 0.30 | 0.96 | 0.77 | 8.81 | 27.39 |
| FTP Cold | Mercedes 220D | 0.13 | 0.84 | 0.68 | 9.54 | 24.75 |
| | Mercedes 240D | 0.17 | 0.62 | 0.80 | 9.50 | 24.81 |
| | Mercedes 300D | 0.10 | 0.55 | 1.10 | 10.53 | 22.36 |
| | Peugeot 204D | 0.69 | 1.07 | 0.44 | 6.94 | 33.99 |
| | Perkins 6-247 | 0.48 | 1.86 | 0.99 | 9.70 | 24.25 |
| | Average | 0.31 | 0.99 | 0.80 | 9.24 | 26.03 |
| FTP Hot | Mercedes 220D | 0.11 | 0.76 | 0.65 | 9.10 | 27.23 |
| | Mercedes 240D | 0.12 | 0.59 | 0.77 | 8.61 | 27.39 |
| | Mercedes 300D | 0.09 | 0.46 | 0.95 | 8.54 | 27.54 |
| | Peugeot 204D | 0.72 | 1.08 | 0.39 | 6.54 | 35.97 |
| | Perkins 6-247 | 0.50 | 1.77 | 0.87 | 8.81 | 26.85 |
| | Average | 0.26 | 0.93 | 0.72 | 8.23 | 29.14 |
| FET | Mercedes 220D | 0.08 | 0.48 | 0.56 | 7.03 | 33.47 |
| | Mercedes 240D | 0.06 | 0.38 | 0.80 | 6.98 | 33.74 |
| | Mercedes 300D | 0.06 | 0.36 | 0.99 | 7.84 | 30.03 |
| | Peugeot 204D | 0.48 | 0.57 | 0.34 | 5.40 | 43.80 |
| | Perkins 6-247 | 0.57 | 1.40 | 0.94 | 8.32 | 28.33 |
| | Average | 0.25 | 0.83 | 0.73 | 7.11 | 33.87 |
| SET | Mercedes 220D | 0.06 | 0.55 | 0.57 | 7.49 | 31.44 |
| | Mercedes 240D | 0.06 | 0.45 | 0.78 | 7.32 | 32.16 |
| | Mercedes 300D | 0.08 | 0.39 | 0.98 | 8.05 | 29.27 |
| | Peugeot 204D | 0.54 | 0.71 | 0.33 | 5.61 | 41.91 |
| | Perkins 6-247 | 0.69 | 1.58 | 0.86 | 8.42 | 27.94 |
| | | 0.29 | 0.74 | 0.70 | 7.38 | 32.54 |

---

*Comprex equipped

the 1975 FTP and FET results, since these are the most popularly used for comparison to other vehicles and, of course, current and future emission tests. The summarized data is the average of three replicate runs which exhibited quite satisfactory repeatability. It is interesting to look at HC by vehicle for the 1975 FTP. HC for the Peugeot 204D and Perkins 6-247 were substantially higher than the three Mercedes cars. CO was also higher with the Perkins and Peugeot than the three Mercedes cars. Oxides of nitrogen were lowest for the Peugeot 204D and Mercedes 220D Comprex. In comparing these g/km emission rates to the more familiar g/mile units, it may be helpful to remember to multiply the g/km by 1.609 to obtain g/mile.

The fuel consumption values, in ℓ/100 km illustrate the superior fuel consumption of the 1134 kg test weight Peugeot 204D. The 6.72 ℓ/100 km relates to 35.86 mpg on the city or 1975 FTP. This is in contrast to nominal 25 mph fuel economy of most diesel cars. The FET results emphasize the fuel consumption importance of the diesel. Again the Peugeot 204D was lowest of the five vehicles with 5.4 ℓ/100 km or 43.8 mpg fuel economy.

The major results of particular importance was the relatively low $NO_x$ of the Mercedes 220D Comprex and the Peugeot 204D. The Comprex likely resulted in the low exhaust $NO_x$ due to internal exhaust gas recirculation, an inherent feature of this method of forcing air into the engine.

The Peugeot 204D was especially noteworthy since this is a production car sold in Europe. The 0.42 g/km $NO_x$ relates to 0.68 g/mile, which is nearer the stringent $NO_x$ regulation of 0.4 g/mile for passenger cars than any other diesel yet evaluated. It remains to be seen if fuel injection improvements can cut HC and CO without raising $NO_x$. It would be interesting to take the 204D and attempt to reduce $NO_x$ to 0.4 g/mile while reducing HC and CO by combination of retard-EGR etc. and improved injection. Also as expected, the Perkins 6-247, at 4500 lbs test weight, had the poorest FET economy even though FTP economy was quite respectable.

The Perkins powered pick-up truck received four 1975 FTP tests at a higher test weight of 2495 kg (5500 lbs) instead of the 2041 (4500 lbs) summarized on Table 23. These runs made at the higher power setting required for the higher test weight resulted in an average 0.64 g/km HC (1.03 g/mile), 2.45 g/km CO (3.94 g/mile), 0.97 g/km $NO_x$ (1.45 g/mile) and 10.0 ℓ/100 km fuel economy (23.5 miles per gallon) was obtained. Repeatability of tests during the 2495 kg series was equally good as that shown above for 2041 kg test weight.

Appendix G contains the computer printout sheets for the gaseous emissions and fuel economy for the five cars. The computer sheets are grouped by each vehicle beginning with FTP then SET and FET results.

### 3. Comparison to EPA Results

Three of the five cars had been tested at EPA Ann Arbor laboratories before being shipped to SwRI. Table 24 is a summary of the test data provided by Mr. Jack McFadden of EPA for the replicate 1975 FTP and FET tests performed at Ann Arbor. Also shown is the average result for the same three cars when tested at SwRI for comparison. Overall, the correlation must be termed very satisfactory. In many cases excellent agreement is shown.

SwRI found slightly lower HC and $NO_x$ on the FTP and slightly lower $NO_x$ on the FET on the Mercedes Comprex. Fuel consumption was in good agreement. For the Mercedes 240D, $NO_x$ was just slightly lower on the FTP and FET at SwRI. For the low $NO_x$ Peugeot 204D, however, $NO_x$ was about the same. The SwRI HC for the Peugeot during the FTP agreed best with the 6-05-75 EPA run, the last one made before shipping the car. For some reason, CO was found to be lower during the SwRI tests than the EPA tests. Otherwise, the lab to lab agreements are quite acceptable. The five vehicles were tested at SwRI in a two-week period, the Mercedes 300D and 240D the first week and the remaining cars on the second week. The same test crew, dynamometer, CVS, fuel and instruments were employed during the two-week test period.

## B. Smoke

The primary evaluation of visible smoke was intended to be the FTP, city, transient driving schedule. Also run were the FET and SET. Also run were simulated Federal Smoke Tests on four of the cars.

### 1. Transient Cycle Smoke

A series of transient driving tests was made with each vehicle using the U. S. EPA smokemeter. Evaluation of the traces has, of necessity, been of a visual judgmental basis since no specific procedure has yet been developed or suggested using any of the transient, mostly light duty schedules. A well designed diesel engine will not smoke appreciably until the last 10 to 15 percent of power demand, something that infrequently happens on any of the transient driving cycles even for the relatively low power to weight diesel powered cars tested.

#### a. 1975 FTP Smoke

Table 25 is a listing of smoke values in percent opacity considered important from a visual analysis of the traces. It was decided to look for those conditions which might produce maximum noticeable smoke during the cold as well as the hot start portion of the test of the 1975 FTP. Since three tests were made, three sets of readings are listed for each segment of the LA-4 route evaluated. Table 25 starts with the initial cold

## TABLE 24. COMPARISON OF SWRI TO EPA AVERAGE TRANSIENT RESULTS

| Vehicle | Test Type | Test Lab | Test No. | Test Date | Emissions, g/km | | | Fuel Cons. litre/100 km |
|---|---|---|---|---|---|---|---|---|
| | | | | | HC | CO | $NO_x$ | |
| **Mercedes 220D Comprex** | **FTP** | **EPA** | 16-9062 | 5-15-75 | 0.14 | 0.84 | 0.86 | 9.5 |
| | | | 16-9085 | 5-16-75 | 0.18 | 0.83 | 0.86 | 9.4 |
| | | | **Average** | | 0.16 | 0.84 | 0.86 | 9.4 |
| | | **SwRI** | **Average** | | 0.11 | 0.81 | 0.65 | 9.1 |
| | **FET** | **EPA** | 16-9062 | 5-15-75 | 0.07 | 0.47 | 0.74 | 7.0 |
| | | | 16-9085 | 5-16-75 | 0.08 | 0.46 | 0.65 | 7.0 |
| | | | 15-9124 | 5-20-75 | 0.07 | 0.48 | 0.75 | 6.8 |
| | | | **Average** | | 0.07 | 0.47 | 0.71 | 6.9 |
| | | **SwRI** | **Average** | | 0.08 | 0.49 | 0.56 | 7.0 |
| **Mercedes 240D** | **FTP** | **EPA** | 15-9215 | 5-29-75 | 0.08* | 0.73 | 0.95 | 9.4 |
| | | | 16-9239 | 5-30-75 | 0.13 | 0.71 | 0.98 | 9.6 |
| | | | **Average** | | 0.13 | 0.72 | 0.97 | 9.5 |
| | | **SwRI** | **Average** | | 0.18 | 0.61 | 0.79 | 9.2 |
| | **FET** | **EPA** | 15-9215 | 5-29-75 | 0.06 | 0.42 | 0.89 | 7.2 |
| | | | 16-9239 | 5-30-75 | 0.06 | 0.40 | 0.90 | 7.3 |
| | | | **Average** | | 0.06 | 0.41 | 0.89 | 7.3 |
| | | **SwRI** | **Average** | | 0.06 | 0.38 | 0.80 | 7.0 |
| **Peugeot** | **FTP** | **EPA** | 16-6280 | 10-24-74 | 1.36 | 1.80 | 0.42 | 7.4 |
| | | | 16-6342 | 10-30-74 | 1.00 | 1.37 | 0.43 | 6.9 |
| | | | 15-7563 | 1-30-75 | 0.63* | 1.71 | 0.43 | 7.1 |
| | | | 16-9322 | 6-5-75 | 0.60 | 1.94 | 0.42 | 7.4 |
| | | | **Average** | | 0.99 | 1.70 | 0.43 | 7.2 |
| | | **SwRI** | **Average** | | 0.69 | 1.06 | 0.42 | 6.7 |
| | **FET** | **EPA** | 16-9281 | ? | 0.81 | 1.01 | 0.35 | 6.0 |
| | | | 16-9369 | ? | 0.36 | 1.00 | 0.34 | 5.7 |
| | | | 15-9300 | ? | 0.41 | 1.07 | 0.34 | 5.9 |
| | | | 16-9322 | 6-5-75 | 0.41 | 1.04 | 0.36 | 6.0 |
| | | | **Average** | | 0.50 | 1.03 | 0.35 | 5.9 |
| | | **SwRI** | **Average** | | 0.48 | 0.57 | 0.34 | 5.4 |

---

*Not by Hot FID, therefore not included in Average

## TABLE 25. SMOKE OPACITY VALUES FROM SMOKE TRACE, 1975 FTP, LA-4 COLD-HOT START

| Smoke Condition | Mercedes 220D* | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|
| Cold Start, Peak % | 35.0 | 25.0 | 29.0 | 97.0 | 66.0 |
| | 99.0 | 47.0 | 27.0 | 87.0 | 63.8 |
| | 76.5** | 40.5 | 54.5 | 96.2 | 63.0 |
| Cold Idle, Avg. % (after start) | 8.8 | 4.8 | 6.0 | 12.0 | 2.4 |
| | 9.3 | 3.5 | 6.0 | 10.0 | 2.5 |
| | 10.5 | 3.0 | 6.5 | 11.0 | 2.0 |
| 1st Accel, Peak % (after cold idle) | 94.5 | 13.8 | 23.0 | 12.0 | 32.5 |
| | 56.5 | 32.5 | 18.5 | 11.5 | 18.7 |
| | 50.5 | 15.0 | 22.7 | 16.0 | 32.5 |
| Idle at 125 Sec, Avg. % | 2.8 | 2.6 | 5.5 | 0.8 | 1.1 |
| | 3.5 | 1.3 | 5.0 | 0.8 | 1.5 |
| | 3.4 | 2.0 | 4.8 | 1.5 | 1.5 |
| Accel at 164 Sec, Peak % to 90.1 km/hr (56 mph) | 20.8 | 24.5 | 23.0 | 6.7 | 34.6 |
| | 43.3 | 10.1 | 22.0 | 8.5 | 35.0 |
| | 43.0 | 25.0 | 17.0 | 15.0 | 35.8 |
| Hot Start, Peak % | 50.0 | 29.0 | 29.0 | 57.0 | 38.7 |
| | 66.5 | 29.5 | 39.0 | 62.0 | 40.0 |
| | 50.0 | 25.0 | 20.0 | 79.5 | 44.1 |
| Hot Idle, Avg. % (after start) | 3.0 | 2.0 | 4.5 | 0.5 | 1.0 |
| | 3.2 | 2.0 | 4.5 | 0.5 | 1.3 |
| | 3.0 | 1.5 | 4.5 | 0.5 | 1.5 |
| 1st Accel, Peak % (after hot idle) | 47.5 | 6.5 | 6.0 | 4.2 | 26.3 |
| | 43.5 | 16.0 | 5.5 | 7.0 | 16.0 |
| | 25.0 | 7.7 | 8.0 | 9.5 | 14.0 |
| Idle at 125 Sec, Avg. % (During Final 505 Sec) | 3.5 | 1.8 | 3.8 | 0.3 | 1.7 |
| | 2.9 | 2.0 | 3.5 | 1.3 | 1.3 |
| | 2.0 | 1.0 | 2.5 | 1.0 | 1.0 |
| Accel at 164 Sec, Peak % to 90.1 km/hr (56 mph) (During final 505 sec) | 55.0 | 8.0 | 10.0 | 3.2 | 33.5 |
| | 52.0 | 10.0 | 8.0 | 4.6 | 37.5 |
| | 65.5 | 6.8 | 8.0 | 3.5 | 37.5 |

---

*Mercedes 220D equipped with Comprex supercharger.

**Repetitive accels after 1st accel ranged from about 30 to 80%.

start which, for the diesel, usually results in a momentary peak value from 25 to 99 percent. Next, the cold idle which occurs immediately after start produced mostly negligible levels except for the Mercedes 220 Comprex and Peugeot 204D. This trend was not consistent at the idle after hot start or at the idle at 125 seconds. In fact, the Mercedes 300D had the highest idle smoke after the initial cold start idle of the five cars.

Next, the initial accel with the still cold engine was rated for its peak or maximum smoke level recorded. Each vehicle and engine responded differently with the Mercedes Comprex producing very high and noticeable peak opacities ranging from 50 to 95 percent opacity. The Perkins 6-247 engine produced the next highest opacities during this initial accel in the range of 19 to 33 percent.

An interesting part of the entire 23-minute LA-4 driving pattern occurs during the first 505 seconds or first bag. Starting at 164 seconds of the test, the vehicle is accelerated from rest to 90.1 km/hr (56 mph). The vehicle undergoes an upshift during this acceleration and for the low power to weight ratio diesel cars, requires generally maximum power or close to maximum power from the engine. In a sense, this accel is similar to the two accels in the EPA HD smoke test procedures. Shown on Table 25 is the average smoke during the idle just prior to the acceleration and the maximum or peak opacity recorded during acceleration to 90.1 km/hr (56 mph).

The accel peak smoke for the five cars is the maximum value measured by the smokemeter and in some instances represented a fairly brief excursion. Some of these peak values occurred twice during the accel and represented the two requirements for power during the speed time trace. In general, the peaks were broader and more sustained than that common to starting with an occasional short puff on top of the smoke trace proper.

Figures 39 to 43 are typical cold start idle-accel to 90.1 km/hr (56 mph) for each of the five cars. The trace represents the first 300 seconds of the cold start and was considered typical. All traces were based on a chart speed of 76.2 mm/min (3 inches/min) with zero opacity equal to 100 percent of chart and 96.5 km/hr (60 mph) equal to 100 percent of chart. In the case of the Mercedes 220 Comprex, 300D, Peugeot 204D and Perkins 6-247, these were for the third test. The Mercedes 240D chart, Figure 40, was for the second test.

In analyzing the smoke traces on Figures 39 - 43 careful attention must be paid the physical distance between recorder pens (offset) since a two-pen overlapping recorder was used. Contrary to what some charts show, acceleration of the engine, vehicle, and smoke output occurred essentially at the same time. Each major chart division from right (engine start) to left is 24.5 mm and is equal to 20 seconds.

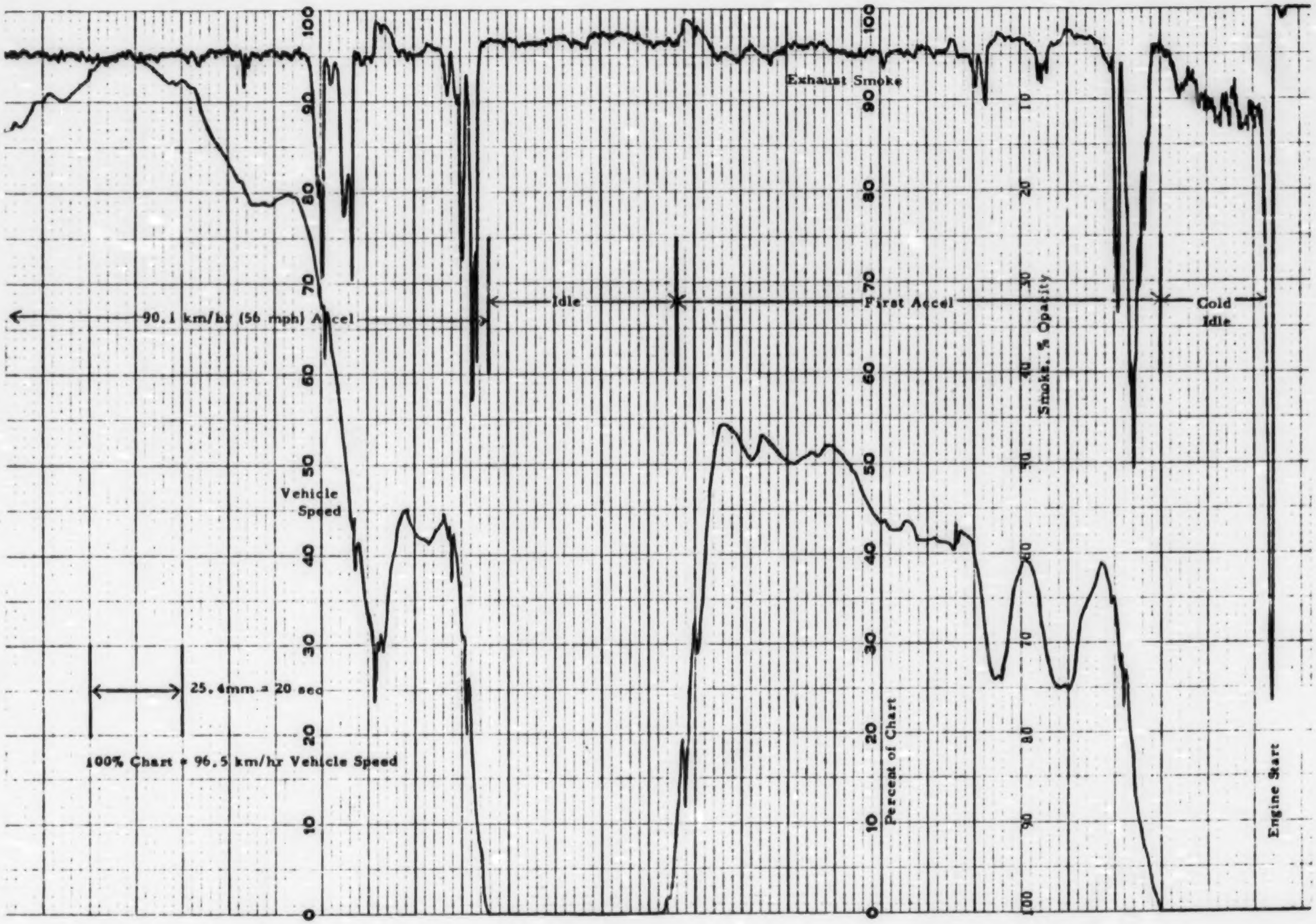


FIGURE 39. TYPICAL MERCEDES 220D COMPREX "COLD START" SMOKE TRACE

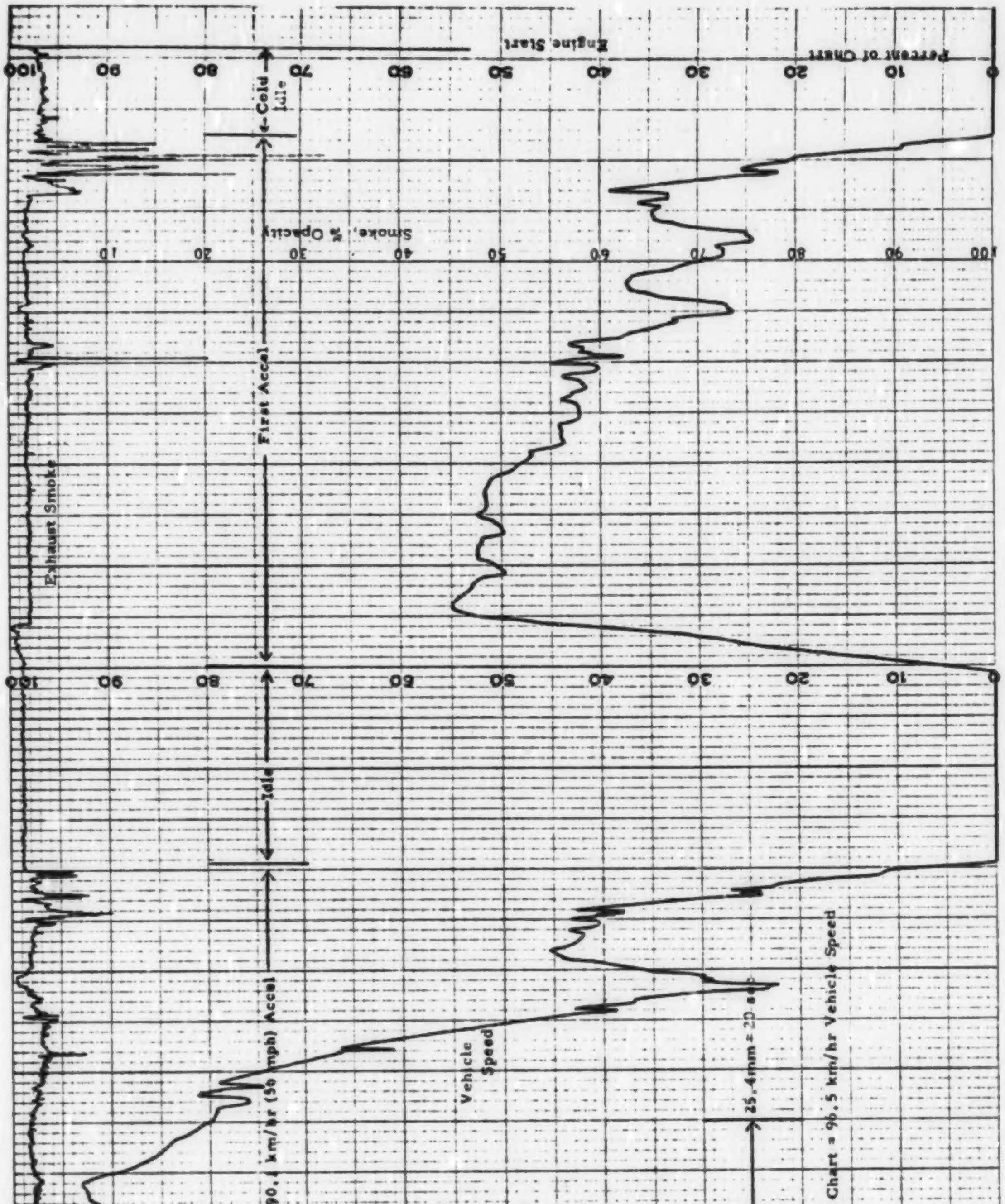


FIGURE 40. TYPICAL MERCEDES 240D "COLD START" SMOKE TRACE

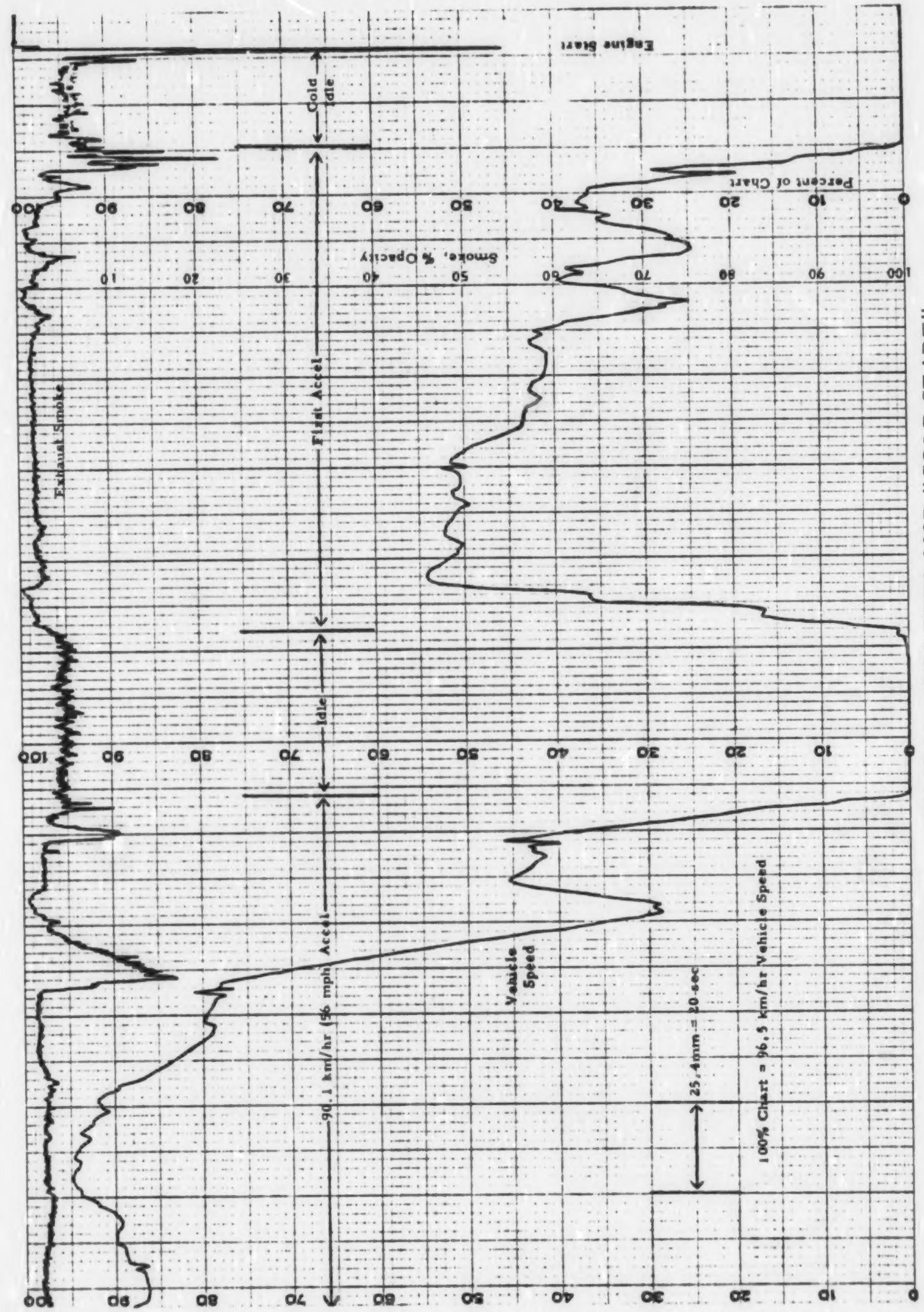


FIGURE 41. TYPICAL MERCEDES 300D "COLD START" SMOKE TRACE

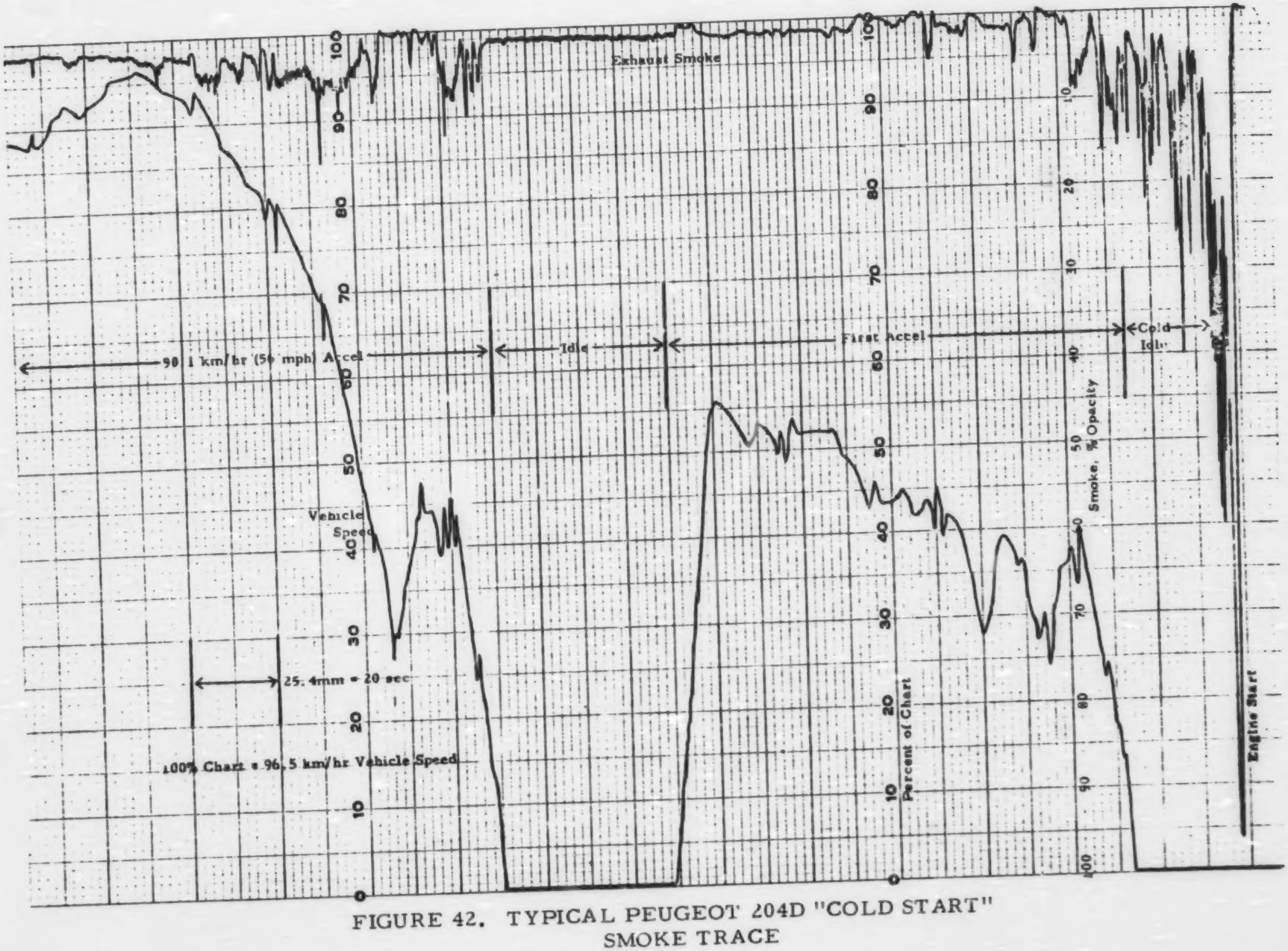


FIGURE 42. TYPICAL PEUGEOT 204D "COLD START" SMOKE TRACE

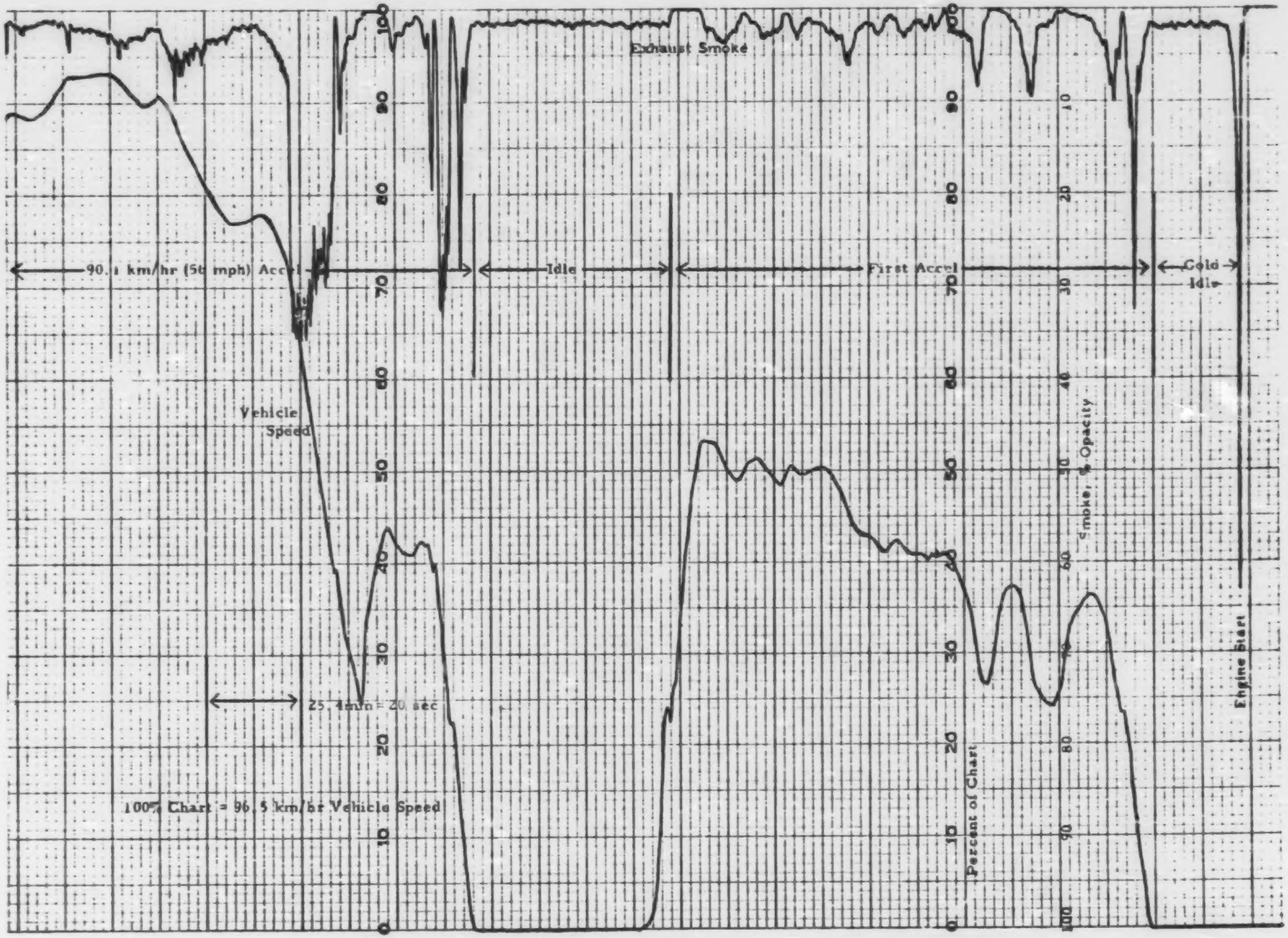


FIGURE 43. TYPICAL PERKINS 6-247 "COLD START" SMOKE TRACE

Table 25 also lists the hot start peak opacity and subsequent idle average opacity readings taken after the prescribed 10 minute soak. Most engines were either the same or slightly lower during the hot start than its cold start. The high Peugeot 204 and Mercedes Comprex cars had some improvement but the peak was still substantial and easily noticeable. The hot start idle readings basically replicated the cold idle values except for the Mercedes Comprex and the Peugeot 204 which were substantially less. The first acceleration in the LA-4 hot start test was generally lower than during the cold start first acceleration in the driving procedure. Except for the Perkins 6-247, the Mercedes and Peugeot diesel cars showed measurable improvement and this may be attributed to the engine being in a warm condition.

The next condition rated was the idle just prior to the acceleration to 90.1 km/hr (56 mph) which repeated the same type of idle but during the cold start part of the test.

The rapid acceleration to 90.1 km/hr (56 mph) during the final 505 seconds resulted in peak opacities that were substantially lower than the same driving sequence performed for the Mercedes 240D, 300D and Peugeot 204D. Oddly enough, the Mercedes 220D Comprex had a higher peak opacity during the high power acceleration after hot start. The Perkins 6-247 resulted in essentially the same smoke peaks.

### b. SET and FET Smoke

Tables 26 and 27 list the visual evaluation made of the smoke measured during the sulfate (SET) and highway economy (FET) cycles. The SET and FET represent cycles of increasing average speed with fewer starts and stops relative to the FTP. These cycles progressively reduce the effect of vehicle inertia (weight) and increase the effect of road load. Thus, it would be expected that more importance be given to cruise than to the accelerations, as was the case with the FTP.

However, all engines were non-turbocharged and therefore steady state and transient effects were not as great as might have been expected. One engine, the Mercedes 220D Comprex, acted in a sense as if it were equipped with a conventional turbocharger. The response of the engine and its smoke behavior was to a great extent similar to a turbocharged engine since acceleration smoke, on the transient driving cycles was always substantially higher than all other cars tested.

TABLE 26. SMOKE OPACITY VALUES FROM SMOKE TRACE OF SET-7 DRIVING CYCLE

| Smoke Condition | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|
| Hot Start, Peak % | 59.0 | 36.0 | 31.5 | 81.0 | 39.0 |
| Idle, Avg. % (after start) | 3.0 | 2.2 | 4.5 | 0.5 | 1.5 |
| 1st Accel, Peak % to 26.1 km/hr | 35.5 | 9.5 | 6.5 | 3.0 | 5.8 |
| Accel at 189 sec, Peak % from 16.1 km/hr to 90.9 km/hr | 35.0 | 4.0 | 5.5 | 6.7 | 24.6 |
| Accel at 527 sec, Peak % from 0 km/hr to 57.1 km/hr | 46.0 | 9.5 | 9.8 | 2.0 | 26.0 |
| Accel at 638 sec, Peak % from 15.6 km/hr to 91.7 km/hr | 32.0 | 5.0 | 4.0 | 3.8 | 26.7 |
| Accel at 944 sec, Peak % from 22.5 km/hr to 90.9 km/hr | 14.5 | 6.3 | 4.5 | 4.5 | 17.7 |

## TABLE 27. SMOKE OPACITY VALUES FROM SMOKE TRACE OF FET DRIVING CYCLE

| Smoke Condition | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|
| Hot Start, Peak % | 49.0 | 9.5 | 26.0 | 91.0 | 36.0 |
| Idle, Avg. % (after start) | 3.5 | 0.5 | 3.5 | 0.5 | 1.3 |
| 1st Accel, Peak % to 79.6 km/hr | 89.0 | 8.0 | 8.0 | 7.5 | 21.5 |
| Accel, Peak % to 94.9 km/hr | 33.0 | 4.0 | 4.5 | 2.0 | 8.5 |

## TABLE 28. EXHAUST SMOKE OPACITY READINGS

(Chassis Version of Federal Procedure)

| Federal Smoke | Mercedes 220D Comprex | Mercedes 240D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|
| "a" factor | 27.0 | 6.0 | 5.7 | 17.0 |
| "b" factor | 37.8 | 3.7 | 3.3 | 19.8 |
| "c" factor | 29.8 | 9.3 | 10.8 | 23.7 |

### 2. Simulated Federal Smoke Test

Four of the cars were run under a chassis version that simulates engine test featured in the Federal Smoke Test for HD vehicles. The Mercedes 300D was incapable of performing the lug-down part of the test because of the automatic transmission and therefore was not run. The results of the chassis dynamometer simulated Federal smoke test are summarized on Table 28. The "a" accel factors are listed first, followed by the "b" lugdown and "c" peak smoke values.

Shown below are the smoke limits specified for the U. S. beginning in 1970 and 1974 calendar years.

| | | Federal Factor, % Opacity | | |
|---|---|---|---|---|
| | | "a" | "b" | "c" |
| Federal HD Limits | 1970 | 40 | 20 | -- |
| | 1974 | 20 | 15 | 50 |

Although chassis version is only a simulation of the Federal Test Procedure, it is helpful to relate to these Federal limits as a frame of reference. The Table 28 "a", "b" and "c" factors for the Mercedes 240D and Peugeot 204D were all well below the Federal limits for 1974 as they should be. The smoke levels of these two diesel cars can better be compared to the threshold of visibility of exhaust smoke which is generally considered to be about three to four percent opacity by the U. S. EPA full flow smokemeter used in this work.

The Mercedes 220D Comprex and Perkins 6-247 both had "a" and "b" factors that are considered high for light duty diesel engines used in LD vehicles. The Perkins 6-247, though lower in smoke than the Comprex, is still very noticeable to the casual observer.

## C. Particulate, Sulfate, $SO_2$ and PNA Results

The use of a dilution tunnel for collecting samples of particulate and sulfate were, for the first time in this long range project, applied to diesel powered cars.

### 1. Particulate

Table 29 lists the particulate emission rates of the five LDV's. These rates are based on both duplicate fiberglass and duplicate Fluoropore filters taken at the same time during FTP cold, FTP hot, FET and

SET experiments. The 1975 FTP is a weighted combination of the cold and hot runs by the expression 1975 FTP = 0.43 FTP cold + 0.57 hot. The fiberglass filter rates are generally taken as the most accurate for gravimetric analysis and particulate determinations. They should be used in preference to the Fluoropore media results. The Fluoropore filters were taken to obtain samples for sulfate. It is interesting to note the agreement by the two collection media, however. Appendix H includes the individual run data on which the Table 29 averages are summarized. Please refer to Appendix H for additional tabulations.

Of the methods for expressing particulate, such as g/test, g/hr, g/kg fuel, g/km is probably the best and most meaningful. Any or all of those listed on Table 29 are helpful in assessing the importance of diesel cars. The particulate rates are shown in the barchart, Figure 44. of the five cars, the Comprex equipped Mercedes 220D and the Perkins 6-247 vehicles had the highest particulate rates. They also have the highest visible smoke discharges of the five cars. The other three vehicles were typically lower with the 240D and 300 nearly identical. Although the Peugeot 204D had the lowest particulate rates of all the cars, it was not possible to sample its tunnel diluted exhaust through the plastic Fluoropore sulfate filter without the filter plugging. This occurred most readily during the hot FTP run.

A visit by Peugeot representatives occurred when this was observed and no reason could be given by Peugeot nor was any reason explainable by the vehicle or engine operation. The oil was changed and oil filter replaced at the advice of Mr. Lucki of Peugeot prior to performing the tests. The deposit on the filter had the smell of "burned oil" or that of blowby gases. Its appearance was quite different also, reminding one of filters from two stroke diesel engines. The two stroke engine is characterized by a particulate that has a higher degree of oil like particulate organic solubles that on occasion are given to plugging of filters.

From the discussions with Peugeot and our other staff members, it was surmised that during the hot run portion of the test, oil or oil-like material was finding its way into the exhaust and plugging the filter. No specific source for this material was found. It had no effect on the life of the 47mm Type A fiberglass membranes. In order to obtain a suitable $SO_4^=$ sample, the sampling probe was redesigned to a smaller diameter and the sampling rate reduced substantially. This, then, was enough to allow full term 23-minute runs to be made without incident.

An interesting comparison one can make from the diesel car data is to examine the particulate rates of these five vehicles relative to gasoline cars run on leaded and lead-free gasoline. If it is assumed that diesel car operation consists of cold FTP, hot FTP, SET and FET

## TABLE 29. PARTICULATE EMISSION RATES
## FIVE DIESEL LDV's (Average of Replicate Runs with 47mm Filters)

| | | Fiberglass | | | Fluoropore | | |
|---|---|---|---|---|---|---|---|
| Test | Vehicle | g/hr | g/kg fuel | g/km | g/hr | g/kg fuel | g/km |
| 1975 FTP | Mercedes 220D* | 11.76 | 5.03 | 0.375 | 11.07 | 4.71 | 0.352 |
| | Mercedes 240D | 9.42 | 3.96 | 0.298 | 8.93 | 3.76 | 0.283 |
| | Mercedes 300D | 9.63 | 3.92 | 0.306 | 8.47 | 3.44 | 0.272 |
| | Peugeot 204D | 7.44 | 4.23 | 0.237 | 6.39 | 3.63 | 0.207 |
| | Perkins 6-247 | 15.72 | 6.68 | 0.500 | 14.51 | 6.11 | 0.461 |
| | Average | 10.79 | 4.76 | 0.343 | 9.87 | 4.33 | 0.315 |
| FTP Cold | Mercedes 220D | 12.75 | 5.14 | 0.411 | 11.94 | 4.75 | 0.379 |
| | Mercedes 240D | 10.05 | 4.00 | 0.319 | 9.66 | 3.85 | 0.306 |
| | Mercedes 300D | 9.63 | 3.47 | 0.307 | 8.27 | 2.96 | 0.269 |
| | Peugeot 204D | 7.77 | 4.53 | 0.263 | 6.91 | 3.76 | 0.218 |
| | Perkins 6-247 | 16.56 | 7.09 | 0.526 | 15.04 | 6.30 | 0.478 |
| | Average | 11.35 | 4.85 | 0.365 | 10.36 | 4.32 | 0.330 |
| FTP Hot | Mercedes 220D | 11.03 | 4.94 | 0.349 | 10.42 | 4.69 | 0.331 |
| | Mercedes 240D | 8.95 | 3.93 | 0.284 | 8.38 | 3.69 | 0.266 |
| | Mercedes 300D | 9.63 | 4.27 | 0.306 | 8.62 | 3.82 | 0.274 |
| | Peugeot 204D | 7.17 | 3.99 | 0.218 | 6.00 | 3.54 | 0.189 |
| | Perkins 6-247 | 15.09 | 6.37 | 0.481 | 14.11 | 5.96 | 0.449 |
| | Average | 10.37 | 4.70 | 0.328 | 9.51 | 4.34 | 0.302 |
| FET | Mercedes 220D | 18.64 | 4.02 | 0.237 | 18.49 | 3.99 | 0.236 |
| | Mercedes 240D | 15.27 | 3.35 | 0.195 | 13.68 | 3.01 | 0.176 |
| | Mercedes 300D | 18.76 | 3.63 | 0.242 | 17.14 | 3.32 | 0.221 |
| | Peugeot 204D | 14.41 | 4.10 | 0.185 | 14.15 | 4.02 | 0.182 |
| | Perkins 6-247 | 25.95 | 4.79 | 0.335 | 25.36 | 4.68 | 0.327 |
| | Average | 18.61 | 3.98 | 0.239 | 17.76 | 3.80 | 0.228 |
| SET | Mercedes 220D | 14.87 | 4.22 | 0.265 | 13.81 | 3.93 | 0.247 |
| | Mercedes 240D | 12.38 | 3.58 | 0.221 | 11.41 | 3.25 | 0.203 |
| | Mercedes 300D | 12.89 | 3.43 | 0.232 | 12.35 | 3.26 | 0.220 |
| | Peugeot 204D | 8.41 | 3.19 | 0.150 | 7.48 | 2.83 | 0.132 |
| | Perkins 6-247 | 17.18 | 4.33 | 0.307 | 16.71 | 4.21 | 0.299 |
| | Average | 13.15 | 3.75 | 0.235 | 12.35 | 3.50 | 0.220 |

---

* Comprex Equipped

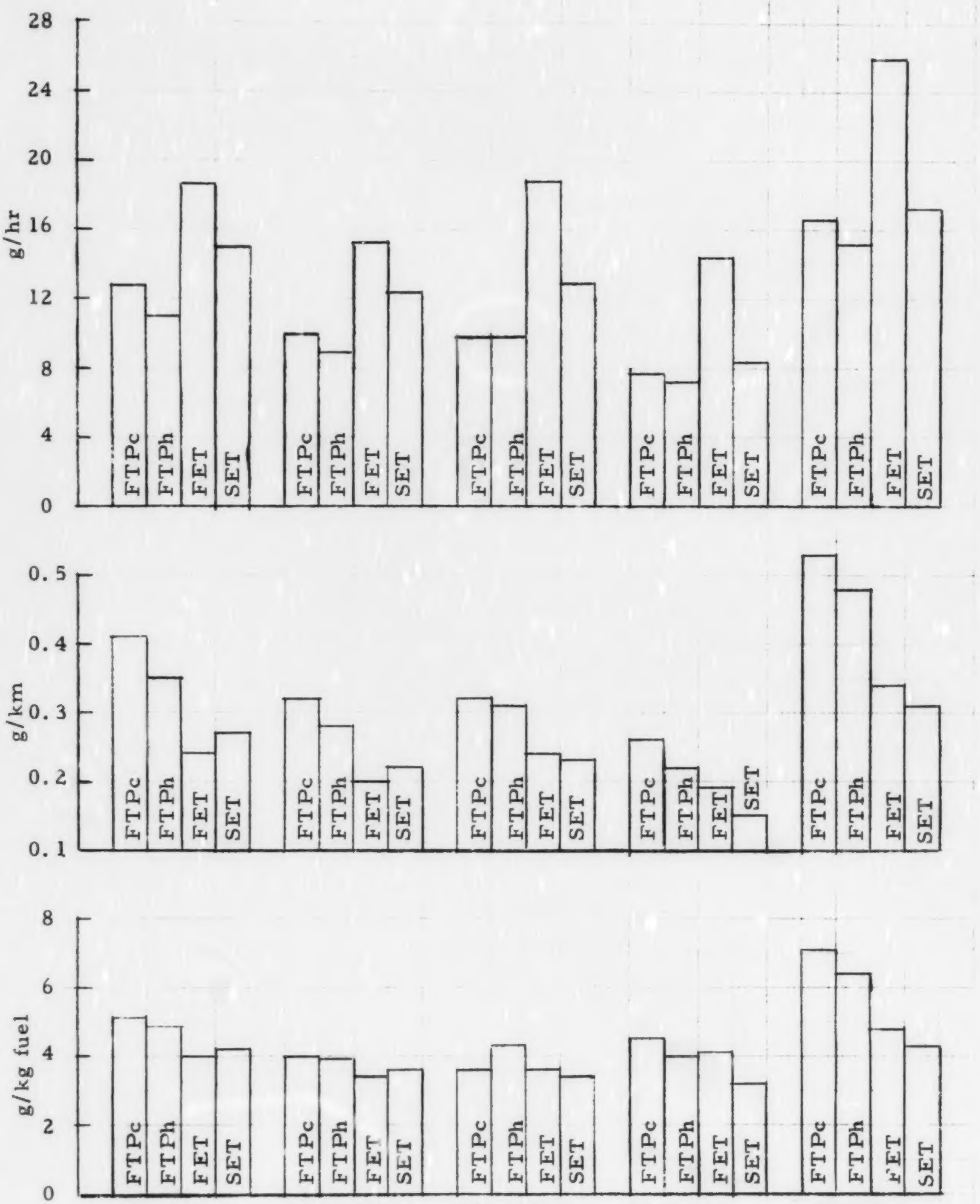


FIGURE 44. PARTICULATE EMISSION RATES OF FIVE DIESEL LD VEHICLES
(Based on 47mm Glass Filters)

type operation, all on an equal basis, then an overall average particulate rate for the five vehicles can be obtained. An average of 0.328 g/km of diesel particulate results from the simple averaging of the average g/km (fiberglass) column of Table 29. This average is, admittedly, a simplistic estimate, but when the range of values (0.150 to 0.526 g/km) is considered, it is probable that a weighted average would not be materially different.

Gasoline car particulate levels in the general literature are quite varied and it is uncertain whether this is a procedural problem, inconsistent test methods, or one of vehicle variability. In any event, a good rough guess of particulate from leaded gasoline fueled cars might be on the order of 0.15 g/km while unleaded gasoline powered cars are on the order of 0.02 g/km. These are very rough figures, but may be used to compare the overall 0.328 g/km particulate rate for five cars and four test cycles. If the 0.328 g/km value may be considered indicative of diesel car particulate emission rates, then the diesel car is on the order of twice that of the car operating on leaded gasoline and fifteen times the unleaded gasoline powered car.

As a very rough frame of reference, early suggestions by EPA, prior to removal of lead from gasoline, indicated possible particulate limits starting initially at 0.06 g/km and eventually becoming as stringent as 0.02 g/km. The diesel car is 5.5 to 16 times these earlier suggestions. It should be noted that plans for particulate emission regulations for automobiles were set aside when the auto makers called for lead-free fuel. The test procedure and data base used for the suggested limits were not well defined so use of these values is not necessarily recommended.

### 2. Elemental Analysis

Table 30 lists the percent by weight of the analysis for carbon, hydrogen and sulfur made of the particulate collected on the 47 mm fiberglass filter. One filter of the two obtained was used for carbon and hydrogen and the other used for sulfur determination.

The carbon content was typically on the order of 75 percent for all cars except the Peugeot 204D. Substantially less of the particulate analyzed as carbon, on the order of 55 percent. Also worthy of note was the observation of slightly but consistently higher carbon during the SET. Exception to this was the Perkins data.

TABLE 30. ELEMENTAL ANALYSIS OF FIBERGLASS FILTER DILUTION TUNNEL COLLECTED PARTICULATE, % BY WEIGHT

| Element | Cycle | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|---|
| Carbon | FTPc | 75.48 | 78.69 | 75.89 | 46.91 | 73.46 |
| | FTPh | 72.48 | 76.81 | 74.73 | 51.37 | 75.50 |
| | SET | 83.20 | 81.50 | 79.99 | 59.59 | 73.56 |
| | FET | 77.89 | 67.51 | 72.60 | 57.96 | 71.51 |
| Hydrogen | FTPc | 2.35 | 3.22 | 2.65 | 6.95 | 3.73 |
| | FTPh | 2.29 | 3.81 | 2.64 | 8.07 | 3.96 |
| | SET | 2.24 | 3.58 | 2.70 | 8.47 | 4.91 |
| | FET | 2.56 | 3.49 | 3.13 | 9.33 | 5.16 |
| Sulfur | FTPc | 2.84 | 4.27 | 4.93 | 5.35 | 2.26 |
| | FTPh | 2.67 | 4.73 | 4.49 | 3.84 | 1.81 |
| | SET | 2.54 | 3.28 | 2.85 | 4.11 | 1.65 |
| | FET | 2.79 | 4.77 | 2.98 | 3.96 | 2.12 |

Just as carbon was lowest for the Peugeot so was hydrogen much higher, on the order of two to three times that of the other four cars. What this infers is that the particulate has a higher degree of hydrocarbon matter and not nearly as much soot or carbon black as the other cars. The higher amount of hydrocarbon matter such as unburned or partially burned fuel and lubricating oil would confirm the earlier discussion regarding filter appearance and the Fluoropore filter plugging encountered with this car.

Listed last on Table 30 are the elemental sulfur values. In Section IV, the ASTM method used to analyze elemental sulfur was reported to have since been replaced by X-ray fluorescence. Though the values seem consistent within a given car and from car to car, they should be used with caution beyond a qualitative comparison. Such comparisons should be limited to the data on Table 30.

### 3. Sulfate and $SO_2$

Table 31 is a summary of the $SO_4^=$ and $SO_2$ results for the FTP cold, FTP hot, FET and SET. The 1975 FTP is a mathematical combination of the cold and hot FTP's. Probably the SET test is the most important of the various cycles evaluated. Both mg/km ($SO_4^=$) or g/km ($SO_2$) are the important rates. Figure 45 is a bar chart of the various sulfate emission rates and depicts how each vehicle behaved for each of the four test cycles. Note that the Mercedes 220D Comprex and Peugeot 204D had about half the $SO_4$/km as that of the Mercedes 300D and the Perkins 6-247. Although it is uncertain why this is so, it is probably due to different reasons. All vehicles used the DF-2 national average fuel doped to 0.23 percent by weight sulfur.

Another important column of data for $SO_4^=$ and $SO_2$ is the "as % S in Fuel" column. This indicates the amount of sulfur in the fuel that becomes $SO_4^=$ as measured by the current EPA-SwRI method. It is interesting that on the order of 1.6 percent of the fuel sulfur is converted during all city driving cycles, about 1.9 percent with the higher duty cycle SET and about 2.3 percent with the highway driving cycle, the FET. As shown on Table 31, the remainder of the exhaust sulfur compounds is represented by $SO_2$, which typically had 88 to 100 percent of fuel sulfur. Please note the accuracy of $SO_2$ measurement is not considered better than ± 10 percent normally and rarely worse than ± 20 percent. This may sound fairly crude, but when the $SO_2$ test method, a wet collection with BCA finish after several intermediate wet chemical steps, is considered, this is probably current state of the art. What this analysis shows is that nearly all fuel S is converted to $SO_2$, but some, a persistent 1.6 to 2.3 percent, depending on test condition, does show up as sulfate in the tailpipe. The inaccuracy of $SO_2$ measurement therefore makes $SO_2$ measurement of little or no importance in sulfur balance of diesels since the relatively small $SO_4^=$ levels are within the ± accuracy of the $SO_2$ measurement.

## TABLE 31. SULFATE AND $SO_2$ EMISSION RESULTS FIVE DIESEL LDV's (Average of Replicate Runs)

| | | Sulfate ($SO_4^=$) | | | | $SO_2$ | |
|---|---|---|---|---|---|---|---|
| Test | Vehicle | mg/hr | mg/km | mg/kg fuel | as % S in Fuel | g/km | as % S in Fuel |
| 1975 FTP | Mercedes 220D* | 220.7 | 7.02 | 93.5 | 1.34 | 0.35 | 106.8 |
| | Mercedes 240D | 246.9 | 7.92 | 105.1 | 1.51 | 0.32 | 91.7 |
| | Mercedes 300D | 287.5 | 9.15 | 116.2 | 1.67 | 0.31 | 86.1 |
| | Peugeot 204D | 210.3 | 6.69 | 119.0 | 1.71 | 0.26 | 99.6 |
| | Perkins 6-247 | 338.7 | 10.77 | 141.2 | 2.00 | 0.36 | 108.1 |
| | Average | 260.8 | 8.31 | 115.0 | 1.65 | 0.32 | 98.5 |
| FTP Cold | Mercedes 220D | 266.7 | 8.49 | 106.4 | 1.53 | 0.37 | 102.2 |
| | Mercedes 240D | 273.0 | 8.69 | 109.2 | 1.57 | 0.34 | 94.3 |
| | Mercedes 300D | 317.0 | 10.09 | 114.2 | 1.64 | 0.34 | 86.1 |
| | Peugeot 204D | 212.3 | 6.76 | 116.0 | 1.67 | 0.25 | 91.3 |
| | Perkins 6-247 | 345.4 | 10.96 | 136.6 | 1.96 | 0.36 | 96.9 |
| | Average | 282.9 | 9.00 | 116.5 | 1.67 | 0.33 | 94.2 |
| FTP Hot | Mercedes 220D | 186.1 | 5.92 | 83.8 | 1.20 | 0.32 | 97.2 |
| | Mercedes 240D | 230.4 | 7.36 | 102.0 | 1.47 | 0.31 | 91.9 |
| | Mercedes 300D | 265.1 | 8.44 | 117.7 | 1.69 | 0.28 | 86.2 |
| | Peugeot 204D | 209.8 | 6.64 | 121.0 | 1.73 | 0.27 | 105.8 |
| | Perkins 6-247 | 333.7 | 10.62 | 144.8 | 2.03 | 0.37 | 106.5 |
| | Average | 245.0 | 7.80 | 113.9 | 1.62 | 0.31 | 97.5 |
| FET | Mercedes 220D | 548.3 | 7.07 | 119.8 | 1.72 | 0.27 | 101.6 |
| | Mercedes 240D | 790.0 | 10.02 | 174.8 | 2.51 | 0.27 | 101.6 |
| | Mercedes 300D | 873.3 | 11.22 | 170.6 | 2.31 | 0.32 | 102.4 |
| | Peugeot 204D | 540.2 | 6.96 | 154.5 | 2.22 | 0.21 | 99.9 |
| | Perkins 6-247 | 1001.2 | 12.91 | 185.2 | 2.66 | 0.31 | 96.6 |
| | Average | 750.6 | 9.64 | 161.0 | 2.28 | 0.28 | 100.4 |
| SET | Mercedes 220D | 320.0 | 5.72 | 91.0 | 1.31 | 0.25 | 89.0 |
| | Mercedes 240D | 491.1 | 8.77 | 142.7 | 2.05 | 0.25 | 87.0 |
| | Mercedes 300D | 574.9 | 10.27 | 152.2 | 2.19 | 0.26 | 84.4 |
| | Peugeot 204D | 286.2 | 5.10 | 108.5 | 1.60 | 0.20 | 95.1 |
| | Perkins 6-247 | 627.2 | 11.34 | 160.6 | 2.28 | 0.27 | 83.7 |
| | Average | 459.9 | 8.24 | 131.0 | 1.89 | 0.25 | 87.8 |

---

*Comprex Equipped

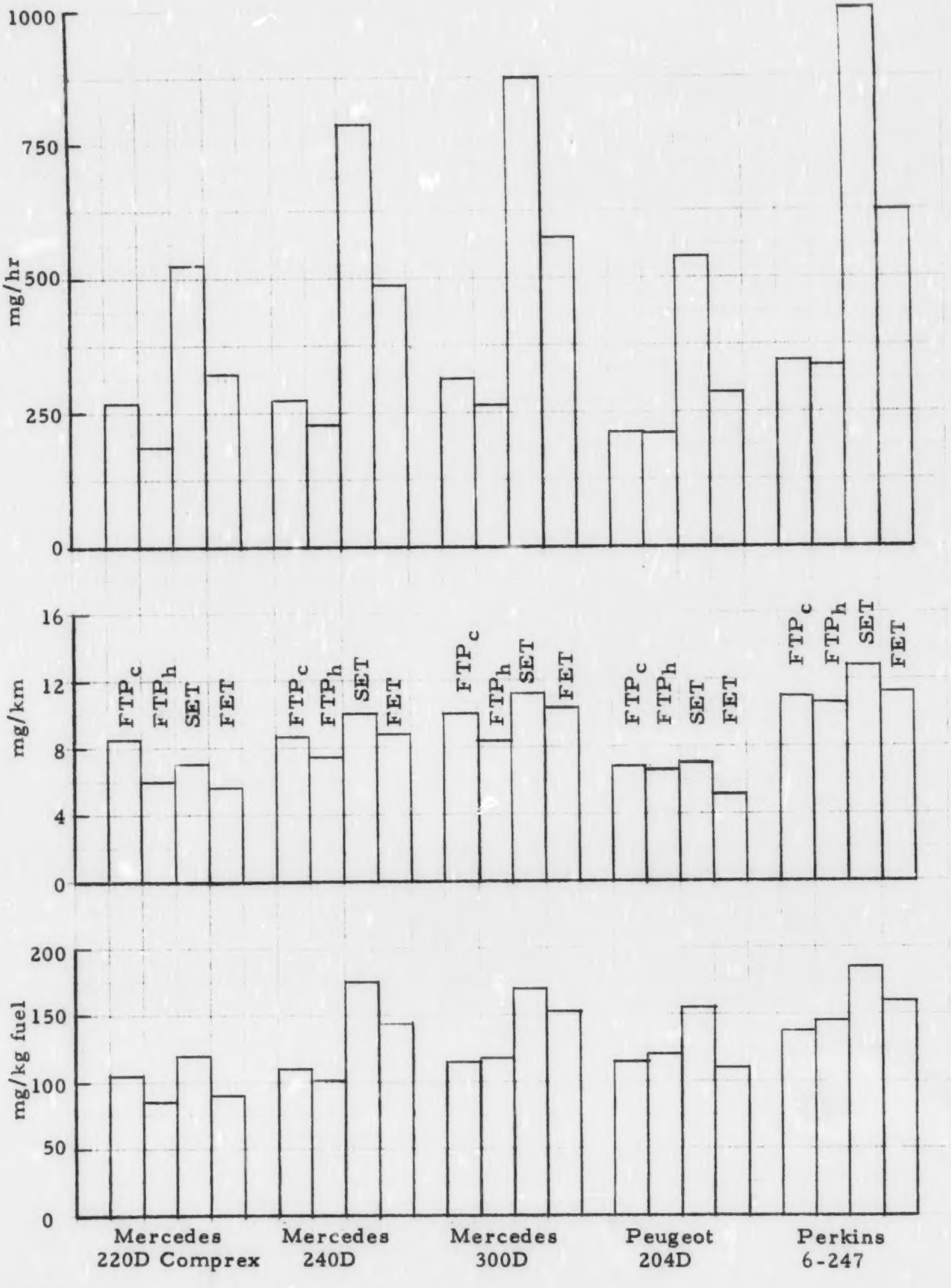


FIGURE 45. SULFATE EMISSION RATES OF FIVE DIESEL LD VEHICLES

For additional sulfate and $SO_2$ data, individual run results, and g/test data, please refer to Appendix I.

If, from Table 31, the self weighting average of the four cycles may be taken as representative of actual driving, and if the five vehicles are illustrative of diesel cars in operation, then the following analogy may be made.

On the assumption that 1.87 percent of the fuel sulfur exits the vehicle as $SO_4^=$, then, for every kg of fuel burned, the contribution of the diesel car is equivalent to 1.87 percent of 0.23 percent fuel sulfur, the current U. S. national average of DF-2 diesel fuel. Catalyst equipped cars can emit a very wide range of $SO_4^=$ as a percent of fuel sulfur, on the order of 0.3 percent to as high as 50 percent by the SET depending on the model, make, and type catalyst, and especially whether or not and how much secondary air injection is used for HC and CO control. Disregarding storage in the catalyst of sulfate, an overall guess at a general value would be on the order of 20 percent conversion.

Thus, for one kg of gasoline, the contribution of the catalyst-equipped gasoline car is equivalent to 20 percent of 0.03 percent fuel sulfur, the current U.S. national average for regular grade gasoline. From this very rough and general comparison, it may be concluded that for the same mass of fuel burned, the diesel car will contribute about half the sulfates as that of an oxidation catalyst-air pump equipped car. It may be argued that the sulfates from gasoline catalyst cars will be reduced by reduced secondary air, different catalyst formulations and other techniques such as trapping. It may also be argued that the diesel car will quite likely consume half as much fuel for the same distance driven due to its superior fuel economy.

The upshot of this discussion is to try and place the diesel car exhaust sulfate into perspective and consider its contribution relative to catalyst equipped cars. One problem in making such comparisons is the tremendous variability in gasoline car $SO_4^=$ levels and the uncertainty over near term solutions and their potential for reduction. Another uncertainty is whether the diesel car sulfates are in the form of sulfuric acid as is the case for gasoline fueled, catalyst-equipped cars. This difference is important to diesel, non-catalyst equipped cars. The health work establishing health effects of sulfuric acid mist has not been done yet. As a consequence, this preliminary comparison must be continually reviewed and improved as more accurate predictions of near term car sulfate production are available.

### 4. Polynuclear Aromatic Hydrocarbons

Table 32 is a summary of particulate rates by means of a third method, that of using a large 203.2 x 254 mm (8 x 10 inch) glass fiber

TABLE 32. B:ESO AND PARTICULATE EMISSIONS RATES - FIVE DIESEL LDV'S
(Average of Replicate Runs with 8 x 10 Glass Filters)

| | | Particulate | | | B:ESO(1) | | | BaP | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test | Vehicle | g/hr | g/kg fuel | g/km | mg/hr | mg/kg fuel | µg/km | mg/hr | mg/kg/fuel | µg/km |
| 1975 FTP | Mercedes 220D* | 11.76 | 5.02 | 0.374 | 1.44 | 0.610 | 45.8 | | | |
| | Mercedes 240D | 10.01 | 4.22 | 0.318 | 1.22 | 0.514 | 38.8 | | | |
| | Mercedes 300D | 10.02 | 4.08 | 0.321 | 2.03 | 0.822 | 64.6 | | | |
| | Peugeot 204D | 7.06 | 3.97 | 0.224 | 3.90 | 2.280 | 124.2 | | | |
| | Perkins 6-247 | 13.25 | 5.51 | 0.417 | 1.06 | 0.442 | 33.7 | 0.775 | 0.115 | 8.73 |
| | Average | | | | | | | | | |
| FTP Cold | Mercedes 220D | 12.41 | 4.95 | 0.395 | 1.66 | 0.660 | 52.7 | | | |
| | Mercedes 240D | 10.78 | 4.31 | 0.343 | 1.31 | 0.524 | 41.7 | | | |
| | Mercedes 300D | 10.95 | 3.95 | 0.349 | 2.18 | 0.788 | 69.6 | | | |
| | Peugeot 204D | 7.86 | 4.28 | 0.249 | 2.36 | 1.290 | 75.0 | | | |
| | Perkins 6-247 | 14.20 | 5.60 | 0.452 | 1.05 | 0.413 | 33.3 | 0.322 | 0.127 | 10.2 |
| | Average | | | | | | | | | |
| FTP Hot | Mercedes 220D | 11.27 | 5.08 | 0.359 | 1.27 | 0.573 | 40.5 | | | |
| | Mercedes 240D | 9.4 | 4.15 | 0.265 | 1.15 | 0.507 | 36.6 | | | |
| | Mercedes 300D | 9.33 | 4.19 | 0.300 | 1.91 | 0.847 | 60.8 | | | |
| | Peugeot 204D | 6.47 | 3.75 | 0.205 | 5.07 | 2.936 | 161.3 | | | |
| | Perkins 6-247 | 12.60 | 5.60 | 0.400 | 1.06 | 0.459 | 33.9 | 0.249 | 0.107 | 7.9 |
| | Average | | | | | | | | | |
| FET | Mercedes 220D | 21.25 | 4.64 | 0.274 | 2.02 | 0.441 | 26.0 | | | |
| | Mercedes 240D | 16.85 | 3.72 | 0.217 | 2.26 | 0.498 | 29.1 | | | |
| | Mercedes 300D | 20.00 | 4.20 | 0.258 | 1.80 | 0.378 | 21.4 | | | |
| | Peugeot 204D | 12.86 | 3.73 | 0.168 | 14.15 | 4.103 | 184.8 | | | |
| | Perkins 6-247 | 21.73 | 4.01 | 0.280 | 1.22 | 0.224 | 15.8 | 0.206 | 0.038 | 2.7 |
| | Average | | | | | | | | | |
| SET | Mercedes 220D | 14.38 | 4.09 | 0.257 | 1.47 | 0.417 | 26.2 | | | |
| | Mercedes 240D | 13.24 | 3.84 | 0.236 | 0.90 | 0.249 | 15.3 | | | |
| | Mercedes 300D | 13.30 | 3.49 | 0.238 | Vial Cracked, Sample Lost | | | | | |
| | Peugeot 204D | 8.09 | 3.06 | 0.144 | 8.17 | 3.091 | 145.4 | | | |
| | Perkins 6-247 | 13.07 | 3.29 | 0.233 | 0.966 | 0.243 | 17.3 | 0.192 | 0.048 | 3.4 |
| | Average | | | | | | | | | |

---

*Comprex Equipped

(1)Expressed as BaP

(Gelman Type A) filter media. The purpose of the large filter, widely used in the popular Hi Vol atmospheric sampler, is to obtain sufficient sample for PNA analysis. The mg/hr, mg/kg fuel and μg/km of B:ESO by the FTP cold and FTP hot were mathematically combined to give an equivalent 1975 FTP value. Figure 46 is a bar chart depicting the emission rates from Table 32 as a function of test cycle for each of the five vehicles.

As with hydrocarbons, the Peugeot produced the highest rates of B:ESO. Since the fuel itself is one source of POM, it follows that the more unburned or partially burned fuel in the exhaust, the more the POM will be. To the writer's knowledge, this is the first time POM, $SO_4^=$, $SO_2$, and particulate emissions have been reported on this variety of diesel powered LDV's. There is little in the literature against which to directly compare these results, and this is especially true in the case of POM and particulate. No work with gasoline powered light duty vehicles has been performed by these same procedures, although some work is in progress for Research Triangle Park Laboratories of EPA by SwRI in support of the fuel additive registration programs. There is, of course, a great amount of sulfate data for gasoline powered cars using the exact same procedures and test cycles. Several years earlier, Exxon reported extensive data on PNA emissions from gasoline powered passenger cars.(41, 42) Although the LD diesel results are higher than that reported by Exxon, the test procedures and sample collection methods were quite different, making a direct comparison difficult.

Also listed on Table 32 are BaP values for the Perkins 6-247 powered IH pick-up truck. Recall from Section III the analysis of POM compounds was made by two methods for the DDAD 8V-71TA HD engine (see Section IV) and the Perkins 6-247 engine. As with the DDAD 8V-71 TA engine, a ratio of BaP to B:ESO may be computed for the Perkins. Based on μg of BaP/km divided by μg of B:ESO/km, the ratios are:

| Cycle | Ratio |
|---|---|
| 1975 FTP | 0.259 |
| FTP cold | 0.306 |
| FTP hot | 0.233 |
| SET | 0.197 |
| FET | 0.171 |

Thus the BaP/B:ESO ratios ranged from 0.171 to 0.306, depending on the transient cycle operated. The highway driving cycle resulted in the least BaP/B:ESO, while the cold FTP resulted in the highest BaP/B:ESO. Overall, the BaP part of the B:ESO was on the order of 20 percent. It is unknown whether this range of BaP/B:ESO will hold for the other four LD diesel vehicles.

## D. Odor and Related Instrumental Analyses

This section covers the odor tests by trained panel and DOAS as well as related instrumental analysis for gaseous emissions, non-reactive hydrocarbons and aldehydes.

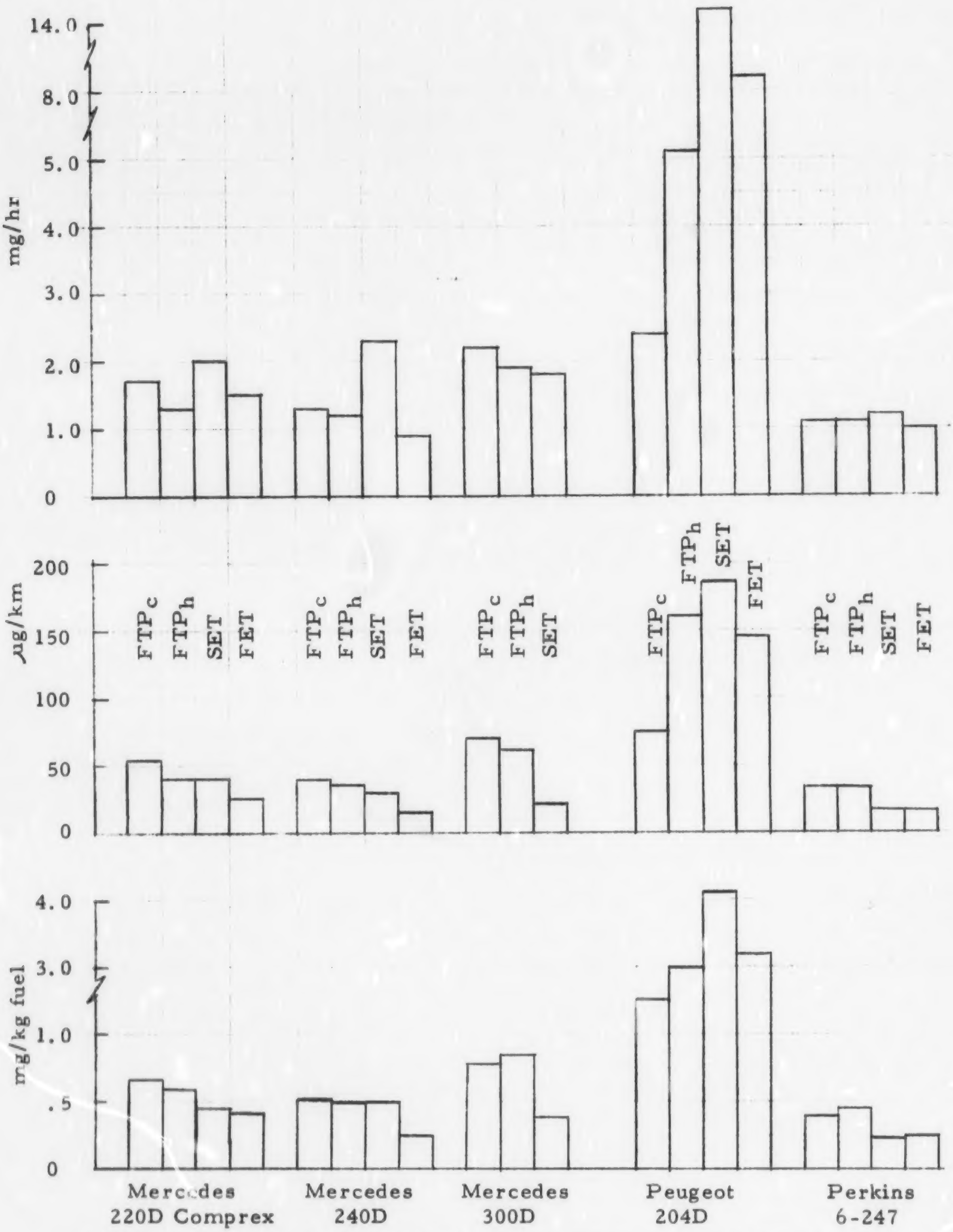


FIGURE 46. B:ESO EMISSION RATES OF FIVE DIESEL LD VEHICLES
(Based on 8 x 10 Glass Filters)

### 1. Odor Ratings by Trained Panel

Table 33 is a listing of the average odor panel ratings for each of the five vehicles. All ratings were made at a dilution ratio of 100:1, 100 parts of prefiltered and conditioned diluent air to 1 part of raw exhaust. Each value listed represents two days of test consisting of six random steady state runs and eight runs during transient. The Peugeot 204D, the first of the five test vehicles, was run three days for nine runs for each steady state run and 12 runs for each transient condition. The day by day, run by run data are listed and summarized in Appendix J.

One way to group the significance of this type of extensive individual mode data is to plot the "D" odor rating against power level for the two speeds evaluated. Recall that the six odor tests in steady state represent a partial odor map. Another way to depict the odor behavior of a vehicle/engine is to sum the panel responses of "D" + "B" + "O" + "A" + "P" for each operation condition. This gives each approximately equal weight to the "D" intensity value and the sum of the four quality ratings and is consistent with prior evaluations.

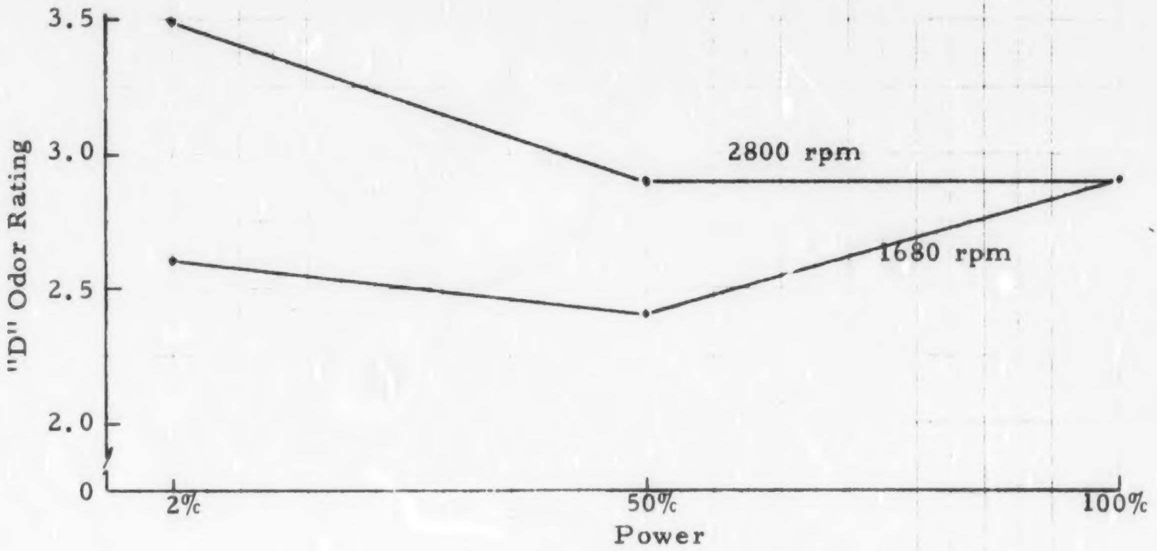
The top half of Figures 47 through 51 show the "D" diesel odor map for six speed-load combinations. The lower half shows the sum of the "D" + "B" + "O" + "A" + "D" ratings. It is interesting to note the behavior of the "D" ratings with speed and load. Except for the Peugeot 204D, the higher speed produced the higher "D" odor. While the Comprex equipped 220D and Perkins 6-247 had lowest odor at 50 percent power, both the Mercedes 240 and 300D had "D" odor levels mostly unchanged with condition. The Peugeot 204D showed an increase in odor with power level.

Unlike many previous diesel car tests in which the transients (accel, decels and idle-accels) were usually higher than the steady states, these tests revealed no substantial consistent difference. The accel after idle (Figure 47, Comprex 220D) cold start (Figure 48 and 49, Mercedes 240D and 300D) were conditons of maximum odor for those three cars. Otherwise, transients were the same, slightly higher or lower than the steady states.

Table 34 is a rough comparison of the odor ratings for the five vehicles. This evaluation indicates that the Perkins 6-247 powered pick-up to be consistently highest in "D" intensity for every grouping such as "six steady states", three transients or the idle and cold start categories of operation. Next highest in "D" odor ratings was the Peugeot 204D and then the Comprex equipped Mercedes 220D. The Mercedes 240D and 300D cars were very similar, except for the idle ratings, giving essentially identical results. This is to be expected for the 240 and 300D engines since the only difference is the number of cylinders (5 versus 4).

## TABLE 33. LISTING OF AVERAGE ODOR PANEL RATINGS AT 100:1 DILUTION

| Vehicle Condition | Odor Kit | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|---|
| STEADY STATE RESULTS | | | | | | |
| Intermediate Speed, 2% Load | D | 2.6 | 2.2 | 2.3 | 3.3 | 4.6 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.4 |
| | O | 0.9 | 1.0 | 0.9 | 1.0 | 1.1 |
| | A | 0.6 | 0.5 | 0.6 | 0.8 | 0.9 |
| | P | 0.5 | 0.4 | 0.5 | 0.8 | 1.1 |
| Intermediate Speed, 50% Load | D | 2.4 | 2.1 | 2.2 | 3.4 | 2.9 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | O | 1.0 | 0.9 | 0.9 | 1.0 | 1.0 |
| | A | 0.5 | 0.6 | 0.5 | 0.9 | 0.6 |
| | P | 0.4 | 0.4 | 0.3 | 0.8 | 0.5 |
| Intermediate Speed, 100% Load | D | 2.9 | 2.4 | 2.0 | 4.1 | 3.7 |
| | B | 1.0 | 1.0 | 1.0 | 1.2 | 1.1 |
| | O | 1.0 | 0.9 | 0.9 | 1.0 | 1.0 |
| | A | 0.8 | 0.5 | 0.4 | 1.0 | 0.8 |
| | P | 0.6 | 0.6 | 0.3 | 1.0 | 0.9 |
| High Speed, 2% Load | D | 3.5 | 2.5 | 2.5 | 3.0 | 4.9 |
| | B | 1.1 | 1.0 | 1.0 | 1.0 | 1.4 |
| | O | 1.0 | 1.0 | 0.9 | 1.0 | 1.2 |
| | A | 0.9 | 0.6 | 0.7 | 0.7 | 0.9 |
| | P | 0.6 | 0.5 | 0.6 | 0.7 | 1.1 |
| High Speed, 50% Load | D | 2.9 | 2.5 | 3.0 | 3.2 | 3.3 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 |
| | O | 0.9 | 1.0 | 1.0 | 1.0 | 1.1 |
| | A | 0.8 | 0.6 | 0.8 | 0.8 | 0.8 |
| | P | 0.7 | 0.6 | 0.6 | 0.7 | 0.9 |
| High Speed, 100% Load | D | 2.9 | 2.7 | 2.8 | 3.6 | 3.8 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| | O | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | A | 0.7 | 0.7 | 0.7 | 0.9 | 0.8 |
| | P | 0.6 | 0.7 | 0.5 | 0.9 | 0.9 |
| Idle | D | 3.1 | 2.1 | 2.9 | 3.8 | 4.2 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.3 |
| | O | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| | A | 0.8 | 0.6 | 0.7 | 0.9 | 0.9 |
| | P | 0.6 | 0.7 | 0.6 | 0.8 | 0.9 |
| TRANSIENT RESULTS | | | | | | |
| Idle-Accel | D | 3.7 | 2.6 | 2.8 | 3.8 | 4.4 |
| | B | 1.1 | 1.0 | 1.0 | 1.1 | 1.2 |
| | O | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| | A | 0.9 | 0.6 | 0.7 | 0.9 | 0.9 |
| | P | 0.9 | 0.7 | 0.5 | 0.9 | 1.0 |
| Acceleration | D | 3.1 | 2.5 | 2.6 | 3.8 | 4.0 |
| | B | 1.0 | 1.0 | 1.0 | 1.1 | 1.2 |
| | O | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 |
| | A | 0.8 | 0.5 | 0.7 | 0.9 | 0.8 |
| | P | 0.7 | 0.6 | 0.4 | 0.9 | 0.9 |
| Deceleration | D | 3.0 | 2.5 | 2.5 | 3.1 | 3.3 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| | O | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | A | 0.6 | 0.6 | 0.8 | 0.7 | 0.9 |
| | P | 0.6 | 0.6 | 0.4 | 0.7 | 0.6 |
| Cold Start | D | 3.1 | 3.2 | 3.4 | 3.4 | 4.5 |
| | B | 1.0 | 1.0 | 1.0 | 1.0 | 1.5 |
| | O | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| | A | 0.7 | 0.9 | 1.0 | 0.7 | 0.9 |
| | P | 0.7 | 0.8 | 0.7 | 0.7 | 1.0 |



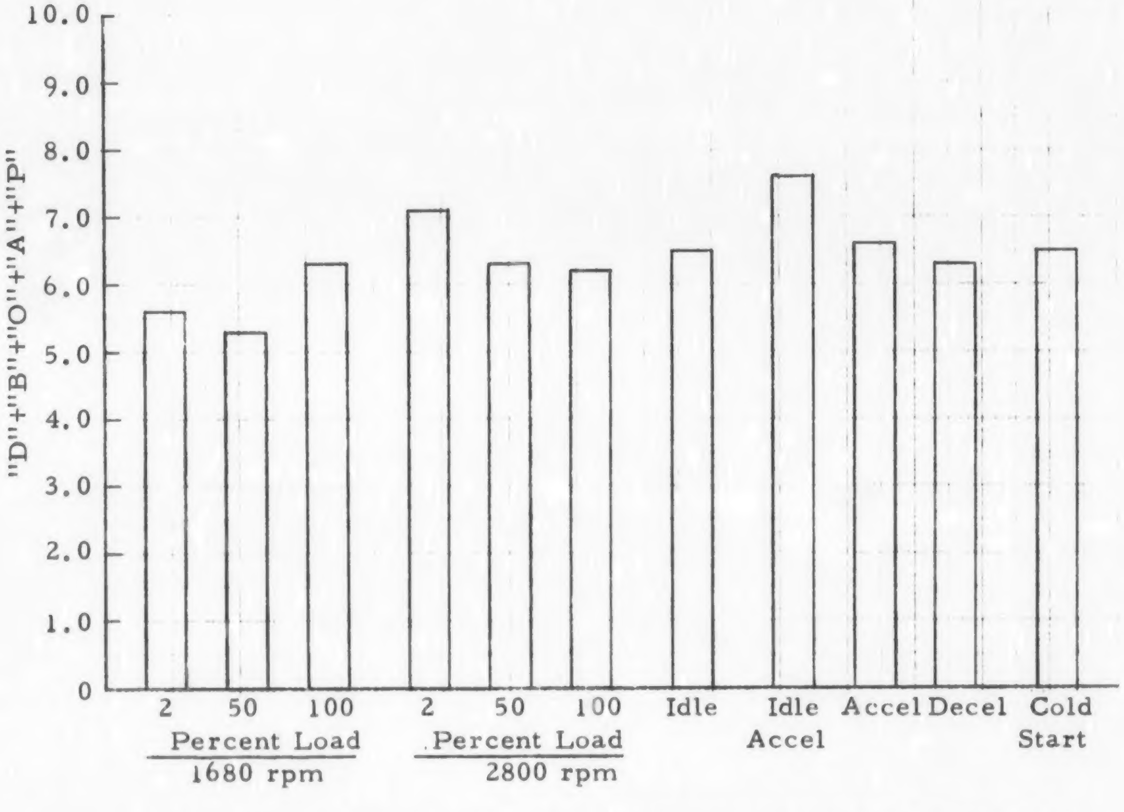
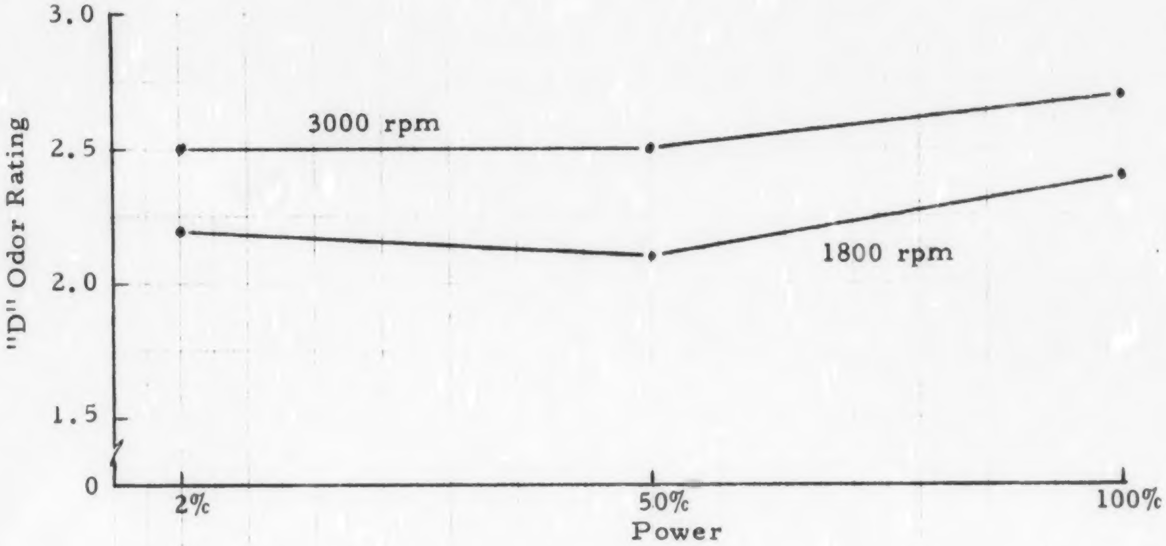


FIGURE 47. AVERAGE ODOR RATINGS FOR MERCEDES 220D COMPREX DIESEL LIGHT DUTY VEHICLE AT 100:1 DILUTION



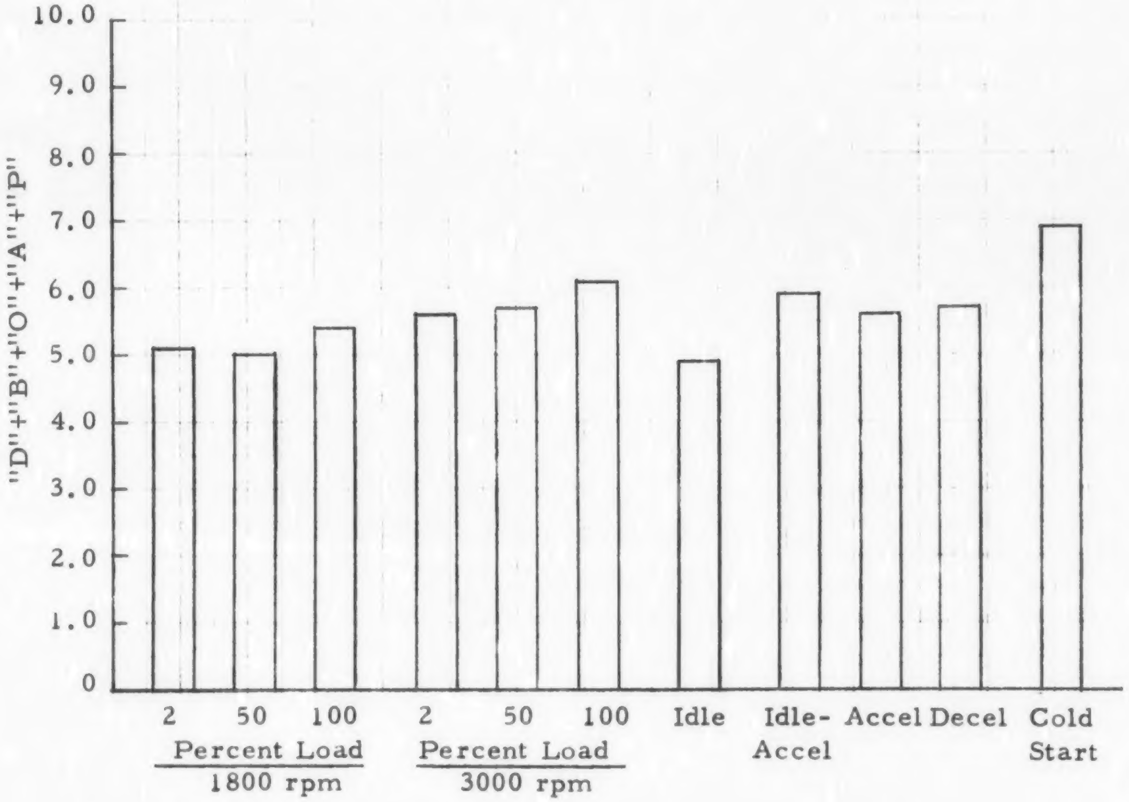


FIGURE 48. AVERAGE ODOR RATINGS FOR MERCEDES 240D DIESEL LIGHT DUTY VEHICLE AT 100:1 DILUTION

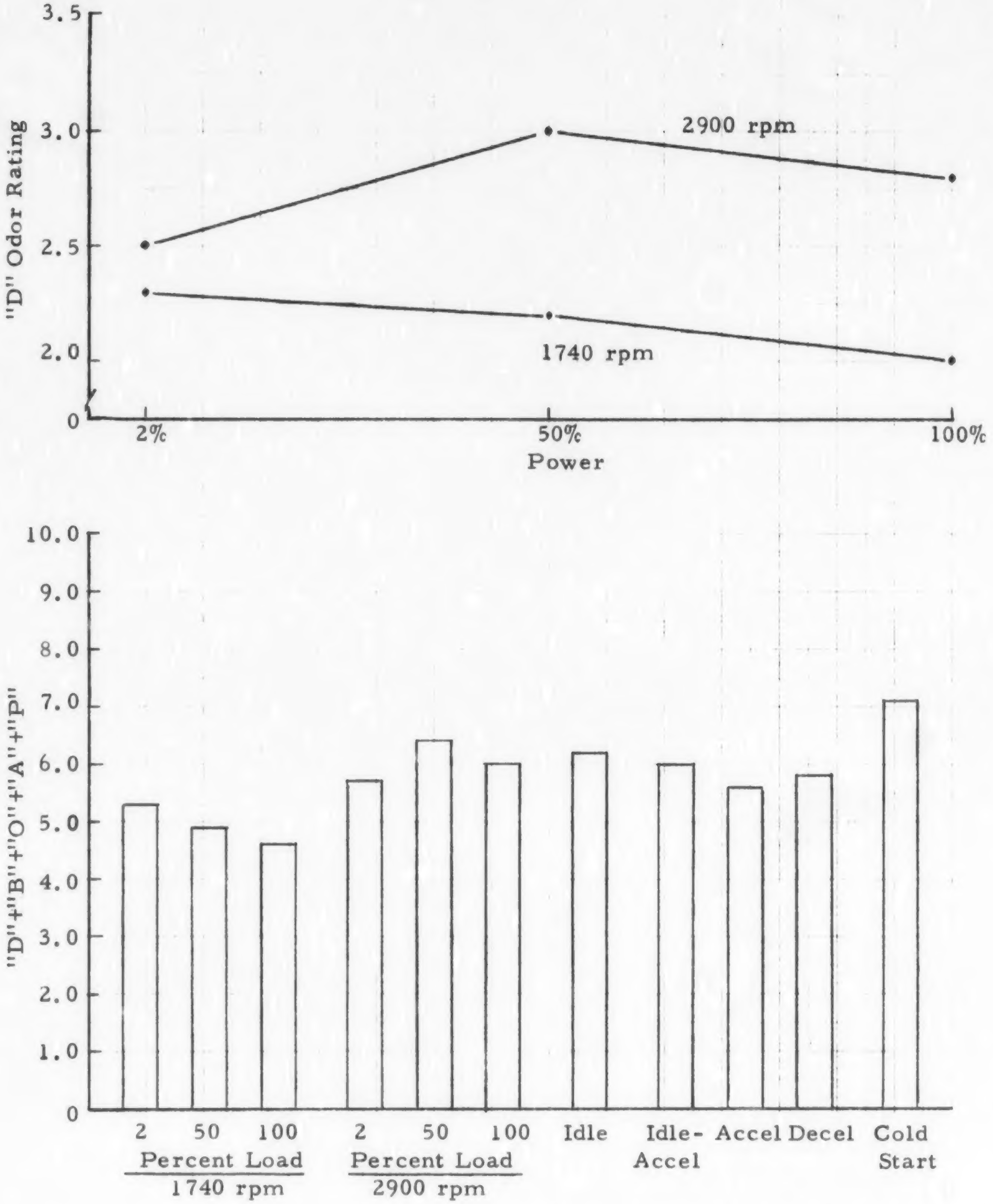
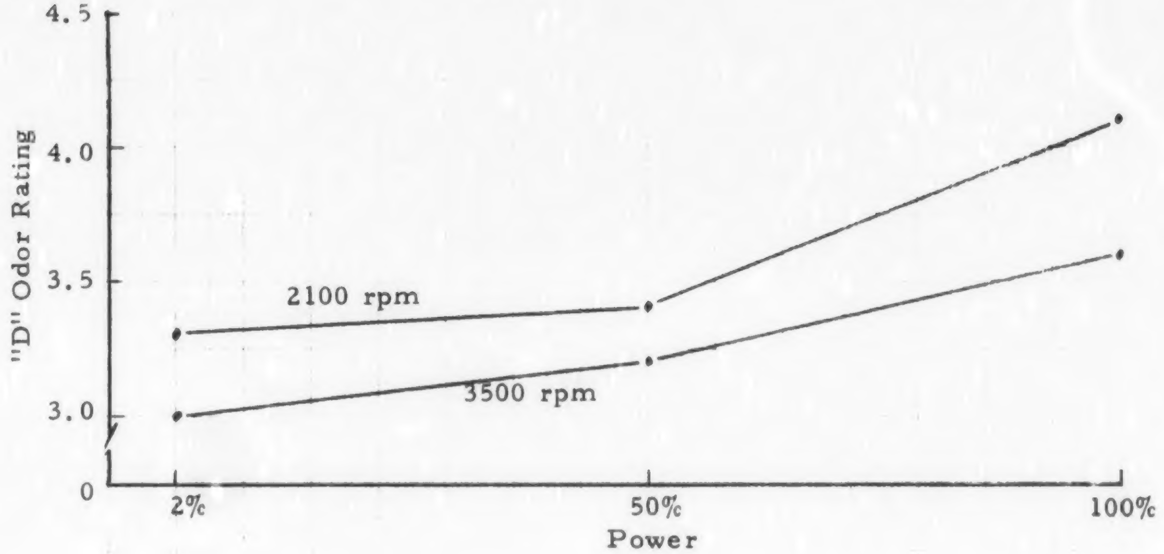


FIGURE 49. AVERAGE ODOR RATINGS FOR MERCEDES 300D DIESEL LIGHT DUTY VEHICLE AT 100:1 DILUTION



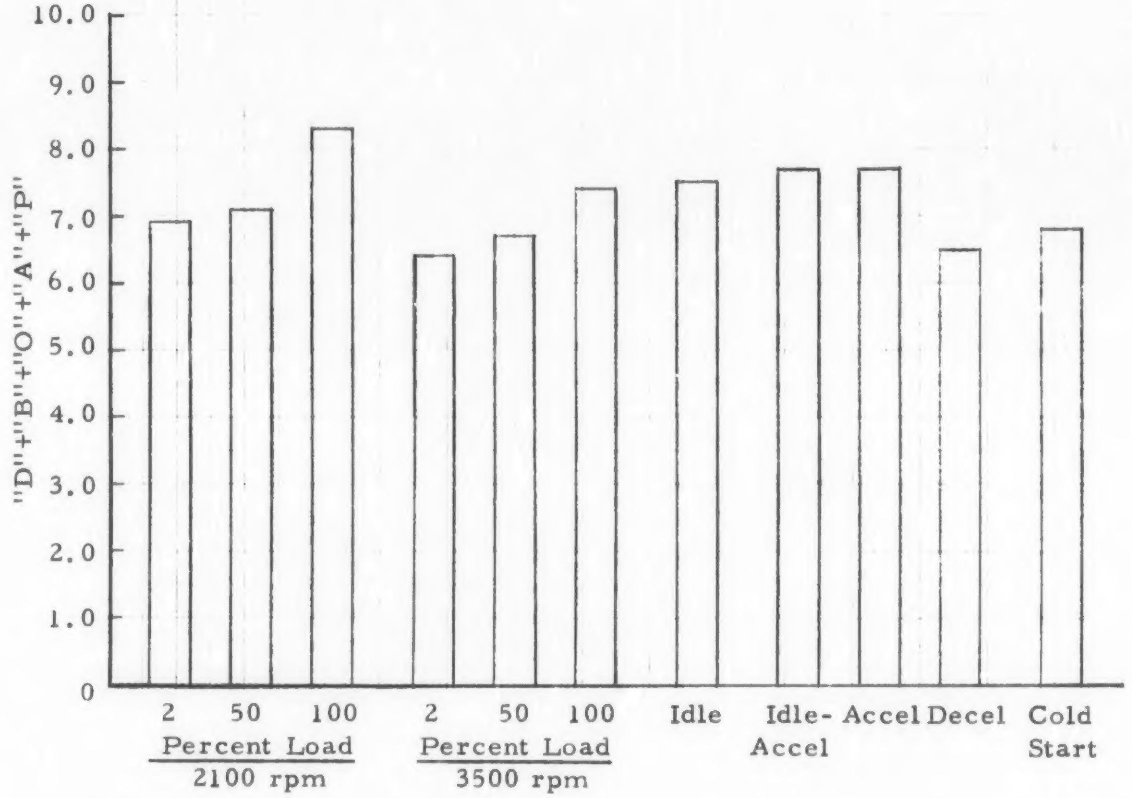


FIGURE 50. AVERAGE ODOR RATINGS FOR PEUGEOT 204D DIESEL LIGHT DUTY VEHICLE AT 100:1 DILUTION

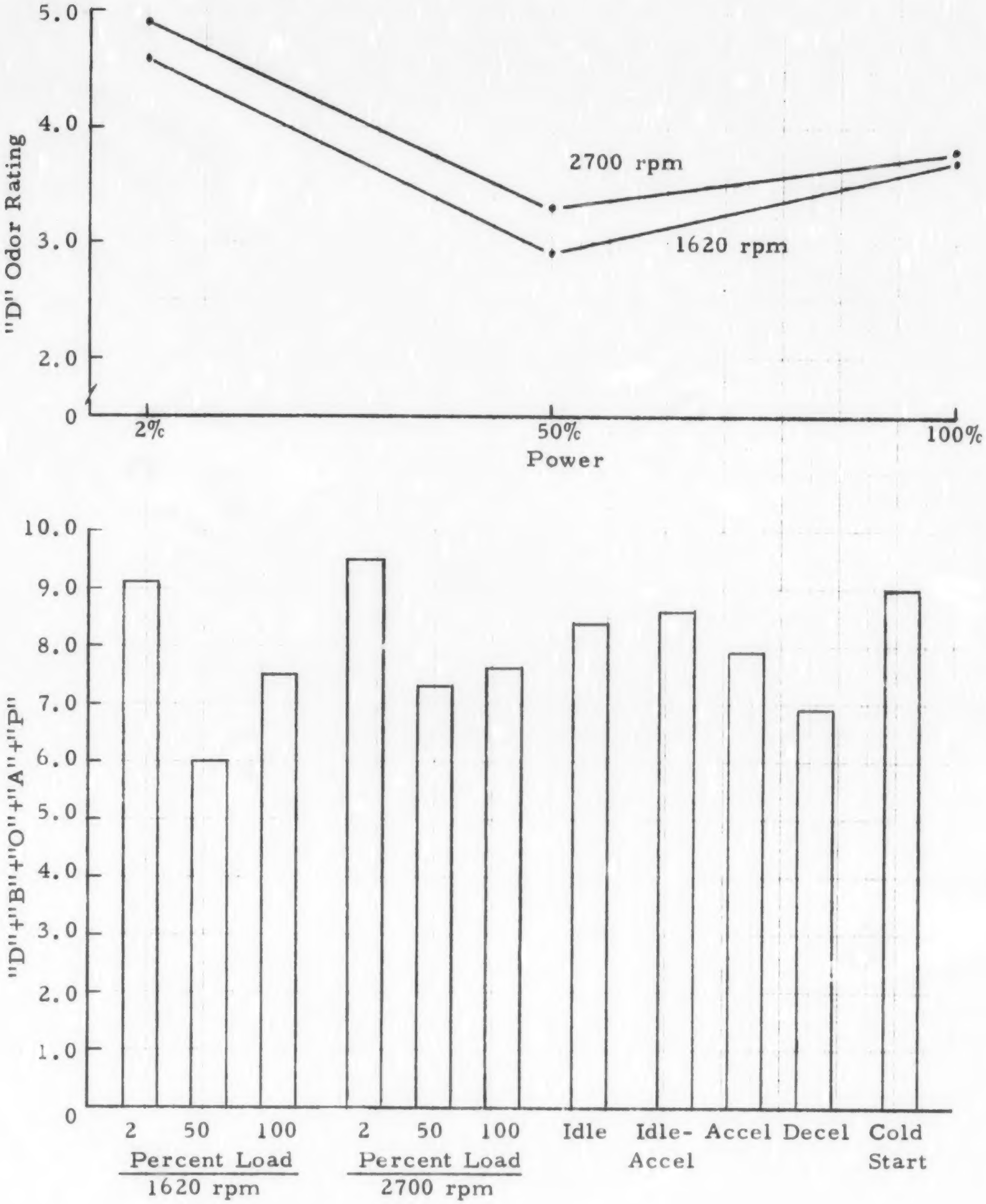


FIGURE 51. AVERAGE ODOR RATINGS FOR PERKINS 6-247 DIESEL LIGHT DUTY VEHICLE AT 100:1 DILUTION

TABLE 34. ROUGH COMPARISON OF LD VEHICLE "D" ODOR RATINGS

| Car Evaluated | Six Steady States | Idle | Cold Start | Three Trans. | All Eleven Conditions |
|---|---|---|---|---|---|
| Mercedes 220D Comp. | 2.9 | 3.1 | 3.1 | 3.3 | 3.0 |
| Mercedes 240D | 2.4 | 2.1 | 3.2 | 2.5 | 2.5 |
| Mercedes 300D | 2.5 | 2.9 | 3.4 | 2.6 | 2.6 |
| Peugeot 204D | 3.4 | 3.8 | 3.4 | 3.6 | 3.5 |
| Perkins 6-247 | 3.9 | 4.2 | 4.5 | 3.9 | 4.0 |

### 2. Gaseous Emissions

Table 35 is a tabulation of the numerous observations of selected gaseous emissions taken simultaneously with the odor panel ratings. The measurements were restricted to the seven steady state operating conditions, six at speed and load and curb idle. Appendix K contains the individual test data for each vehicle. Table 5 in Section III gives fuel rate for each test condition. Each table in Appendix K lists air flow as measured during each test run. Given the fuel rate and air flow, the concentrations of Table 35 may be used to compute a seven mode cycle emissions composite in g/hr or g/kg fuel consumed.

The seven mode cycle, if computed to yield composite emission rates, is not consistent with the 13-mode HD cycle in a number of ways. The six speed and load points for the cars are intentionally selected to represent the way cars operate. The LD diesel operating or duty cycle is unlike that of the HD diesel in a truck or bus making calculations from the emissions data given on Table 35 for a simulated 13-mode HD result inappropriate. Please note that the speeds were selected not at rated and peak torque/intermediate as with the HD 13-mode test but as that engine speed which produces 56 mph, in the highest gear. The lower speed was taken as 60 percent of the 56 mph engine speed.

### 3. DOAS - Simultaneous with Odor Panel

Also listed on Table 35 are the average values obtained by the DOAS simultaneously with the odor panel ratings. Table 36 compares the "D" odor panel rating with the DOAS results for each day of odor testing, each vehicle, and each test condition. Only T1A is listed since this is the odor

## TABLE 35. EXHAUST ANALYSES TAKEN SIMULTANEOUSLY WITH ODOR RATINGS DURING STEADY-STATE CONDITIONS

| Vehicle Condition | Exhaust Emissions | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|---|
| Intermediate Speed, 2% Load | HC, ppmC | 58 | 69 | 79 | 292 | 935 |
| | CO, ppm | 146 | 173 | 187 | 376 | 871 |
| | NO-NDIR, ppm | 120 | 66 | 71 | 36 | 27 |
| | NO-CL, ppm | 112 | 63 | 64 | 32 | 32 |
| | $NO_x$-CL, ppm | 120 | 68 | 73 | 51 | 44 |
| | $CO_2$, % | 2.9 | 2.4 | 2.6 | 2.1 | 2.0 |
| | TIA | 1.8 | 1.6 | 1.6 | 2.1 | 2.5 |
| | LCO, μg/l | 5.9 | 4.1 | 4.4 | 10.6 | 29.6 |
| | LCA, μg/l | 11.7 | 7.3 | 7.5 | 21.8 | 61.9 |
| Intermediate Speed, 50% Load | HC, ppmC | 33 | 68 | 68 | 700 | 306 |
| | CO, ppm | 130 | 149 | 146 | 358 | 407 |
| | NO-NDIR, ppm | 271 | 351 | 189 | 139 | 349 |
| | NO-CL, ppm | 251 | 308 | 167 | 116 | 321 |
| | $NO_x$-CL, ppm | 256 | 309 | 177 | 153 | 326 |
| | $CO_2$, % | 5.7 | 6.7 | 4.4 | 4.7 | 6.8 |
| | TIA | 1.8 | 1.7 | 1.7 | 2.2 | 2.2 |
| | LCO, μg/l | 6.2 | 4.7 | 5.1 | 16.6 | 16.3 |
| | LCA, μg/l | 12.3 | 8.1 | 9.8 | 46.8 | 32.4 |
| Intermediate Speed, 100% Load | HC, ppmC | 42 | 61 | 60 | 843 | 492 |
| | CO, ppm | 2402 | 286 | 132 | 351 | 5094 |
| | NO-NDIR, ppm | 181 | 361 | 276 | 218 | 350 |
| | NO-CL, ppm | 172 | 340 | 243 | 204 | 316 |
| | $NO_x$-CL, ppm | 173 | 344 | 252 | 208 | 326 |
| | $CO_2$, % | 6.7 | 10.8 | 5.6 | 8.6 | 11.3 |
| | TIA | 1.8 | 1.7 | 1.7 | 2.5 | 2.2 |
| | LCO, μg/l | 5.0 | 4.8 | 4.7 | 29.7 | 18.9 |
| | LCA, μg/l | 8.7 | 6.0 | 8.0 | 90.5 | 38.5 |
| High Speed, 2% Load | HC, ppm | 170 | 76 | 61 | 320 | 1305 |
| | CO, ppm | 415 | 353 | 235 | 560 | 869 |
| | NO-NDIR, ppm | 139 | 86 | 104 | 55 | 55 |
| | NO-CL, ppm | 121 | 80 | 88 | 45 | 57 |
| | $NO_x$-CL, ppm | 131 | 84 | 98 | 61 | 71 |
| | $CO_2$, % | 3.8 | 3.1 | 3.1 | 2.9 | 2.6 |
| | TIA | 1.9 | 1.7 | 1.7 | 2.1 | 2.5 |
| | LCO, μg/l | 8.3 | 4.1 | 4.2 | 13.0 | 29.5 |
| | LCA, μg/l | 23.4 | 7.5 | 8.0 | 25.4 | 83.4 |
| High Speed, 50% Load | HC, ppm | 46 | 50 | 43 | 356 | 210 |
| | CO, ppm | 146 | 179 | 159 | 331 | 317 |
| | NO-NDIR, ppm | 364 | 401 | 341 | 206 | 383 |
| | NO-CL, ppm | 334 | 357 | 312 | 188 | 374 |
| | $NO_x$-CL, ppm | 337 | 366 | 320 | 201 | 385 |
| | $CO_2$, % | 6.1 | 7.4 | 6.4 | 6.1 | 7.5 |
| | TIA | 1.8 | 1.7 | 1.7 | 2.3 | 2.2 |
| | LCO, μg/l | 6.3 | 4.9 | 5.2 | 17.1 | 17.5 |
| | LCA, μg/l | 11.4 | 7.2 | 8.8 | 40.7 | 32.9 |
| High Speed, 100% Load | HC, ppm | 38 | 63 | 46 | 377 | 532 |
| | CO, ppm | 1916 | 430 | 148 | 335 | 3795 |
| | NO-NDIR, ppm | 336 | 477 | 490 | 267 | 396 |
| | NO-CL, ppm | 313 | 444 | 456 | 241 | 358 |
| | $NO_x$-CL, ppm | 316 | 444 | 464 | 244 | 371 |
| | $CO_2$, % | 8.0 | 12.2 | 9.4 | 9.2 | 11.9 |
| | TIA | 1.9 | 1.7 | 1.8 | 2.4 | 2.4 |
| | LCO, μg/l | 10.0 | 5.0 | 5.5 | 25.9 | 25.5 |
| | LCA, μg/l | 17.2 | 5.9 | 8.1 | 63.3 | 44.7 |
| Idle | HC, ppm | 102 | 96 | 119 | 539 | 361 |
| | CO, ppm | 154 | 151 | 172 | 517 | 515 |
| | NO-NDIR, ppm | 150 | 95 | 104 | 32 | 53 |
| | NO-CL, ppm | 133 | 87 | 85 | 23 | 59 |
| | $NO_x$-CL, ppm | 139 | 93 | 95 | 50 | 74 |
| | $CO_2$, % | 3.0 | 2.4 | 2.5 | 2.2 | 1.7 |
| | TIA | 1.8 | 1.6 | 1.7 | 2.1 | 2.2 |
| | LCO, μg/l | 7.2 | 3.7 | 4.6 | 12.4 | 15.2 |
| | LCA, μg/l | 16.0 | 7.9 | 10.6 | 25.7 | 20.8 |

## TABLE 36. COMPARISON OF TIA AND "D" ODOR VALUES

| Condition | Day | Mercedes 220 Comprex TIA | Mercedes 220 Comprex "D" | Mercedes 240D TIA | Mercedes 240D "D" | Mercedes 300D TIA | Mercedes 300D "D" | Peugeot 204D TIA | Peugeot 204D "D" | Perkins 6-247 TIA | Perkins 6-247 "D" |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | 1st | 2.0 | 3.1 | 1.6 | 2.2 | 1.7 | 2.6 | 2.1 | 3.9 | 2.2 | 4.4 |
| | 2nd | 1.5 | 3.0 | 1.6 | 2.0 | 1.6 | 3.1 | 2.1 | 3.8 | 2.2 | 3.9 |
| | Avg. | 1.8 | 3.1 | 1.6 | 2.1 | 1.7 | 2.9 | 2.1 | 3.9 | 2.2 | 4.2 |
| Inter. rpm 2% Load | 1st | 1.9 | 2.4 | 1.6 | 2.1 | 1.6 | 2.3 | 2.1 | 3.5 | 2.5 | 4.5 |
| | 2nd | 1.7 | 2.8 | 1.6 | 2.2 | 1.6 | 2.3 | 2.0 | 3.2 | 2.4 | 4.7 |
| | Avg. | 1.8 | 2.6 | 1.6 | 2.2 | 1.6 | 2.3 | 2.1 | 3.4 | 2.5 | 4.6 |
| Inter. rpm 50% Load | 1st | 1.9 | 2.5 | 1.6 | 2.0 | 1.7 | 2.2 | 2.2 | 3.4 | 2.2 | 2.7 |
| | 2nd | 1.6 | 2.2 | 1.7 | 2.2 | 1.7 | 2.1 | 2.2 | 3.3 | 2.2 | 3.1 |
| | Avg | 1.8 | 2.4 | 1.7 | 2.1 | 1.7 | 2.2 | 2.2 | 3.4 | 2.2 | 2.9 |
| Inter. rpm 100% Load | 1st | 1.8 | 2.7 | 1.7 | 2.3 | 1.7 | 1.9 | 2.5 | 4.6 | 2.0 | 3.9 |
| | 2nd | 1.7 | 3.1 | 1.7 | 2.4 | 1.7 | 2.1 | 2.4 | 4.0 | 2.4 | 3.5 |
| | Avg. | 1.8 | 2.9 | 1.7 | 2.4 | 1.7 | 2.0 | 2.5 | 4.3 | 2.2 | 3.7 |
| High rpm 2% Load | 1st | 2.1 | 3.4 | 1.6 | 2.2 | 1.6 | 2.8 | 2.1 | 3.3 | 2.5 | 4.6 |
| | 2nd | 1.7 | 3.5 | 1.7 | 2.8 | 1.7 | 2.2 | 2.1 | 2.9 | 2.4 | 5.1 |
| | Avg. | 1.9 | 3.5 | 1.7 | 2.5 | 1.7 | 2.5 | 2.1 | 3.1 | 2.5 | 4.9 |
| High rpm 50% Load | 1st | 1.9 | 2.9 | 1.7 | 2.6 | 1.7 | 3.2 | 2.3 | 3.0 | 2.0 | 3.2 |
| | 2nd | 1.7 | 2.9 | 1.7 | 2.4 | 1.7 | 2.8 | 2.2 | 3.3 | 2.4 | 3.4 |
| | Avg. | 1.8 | 2.9 | 1.7 | 2.5 | 1.7 | 3.0 | 2.3 | 3.2 | 2.2 | 3.3 |
| High rpm 100% Load | 1st | 2.1 | 2.9 | 1.7 | 2.7 | 1.8 | 3.0 | 2.3 | 3.5 | 2.4 | 4.1 |
| | 2nd | 1.7 | 2.9 | 1.6 | 2.6 | 1.7 | 2.5 | 2.4 | 3.7 | 2.3 | 3.4 |
| | Avg. | 1.9 | 2.9 | 1.7 | 2.7 | 1.8 | 2.8 | 2.4 | 3.6 | 2.4 | 3.8 |

rating or total intensity of aroma value by the DOAS taken as 1 + log LCO. The LCO is an indicator of a class of odorants in diesel exhaust. The T1A is an arbitrary scale of odor intensity based on an assumed chemical odorant: perceived odor relationships. All T1A, LCO and LCA values are given for each observation in Appendix K.

The plot of T1A versus observed "D" rating is shown in Figure 52. Note that the triangles △ and ▽ for the Mercedes 240D and 300D cars cluster together with the squares (Mercedes 220D Comprex) close by and just above the conventional 4 and 5 cylinder results. Then the Peugeot 204D and Perkins 6-247 are at the upper half of the data with the 6-247 having "D" ratings as high as 4.5 to 5.

Overall the relationship is encouraging and much better than that found with five heavy duty engines described in Section IV. There is some question regarding the line of data at T1A of 1.7 where "D"-2 to "D"-3 was observed. The same thing is true for the T1A of 1.8.

### 4. DOAS Results - Transient Cycles

An attempt was made to obtain T1A, LCO and LCA values during the 1975 FTP light duty test procedure. The object was to try and relate transient T1A values to various odor ratings obtained by the eleven mode odor evaluation using the trained panel.

Table 37 lists the DOAS results of samples obtained throughout each of the various driving cycles. The chromosorb trap was used to collect and integrate a dilute exhaust sample throughout each transient test and in this way served as the sample bag to integrate the sample. Figure 53 is a bar chart summary of the average data from Table 37. It is interesting to note the stairstep increase of T1A with the average speed of the cycle. The city FTP has the slowest average speed while the highway FET has the highest average speed.

It is also clear from Figure 53 that the DOAS rates the Perkins as having the highest odor with the Peugeot next highest. Then the Mercedes 220D Comprex was next highest. Of the five cars, the 240D and 300D Mercedes had the lowest DOAS values and they were quite similar. Recall from the earlier discussion of the eleven mode odor panel ratings that this was the order of the observed odor ratings. All this serves to confirm, in a very qualitative way, the correlation shown in Figure 52.

The LCO, which has not been converted into TIA, gives a better comparison of the five vehicles and three test modes. Note the very similar behavior of the LCA values to the LCO, both shown on Figure 53.

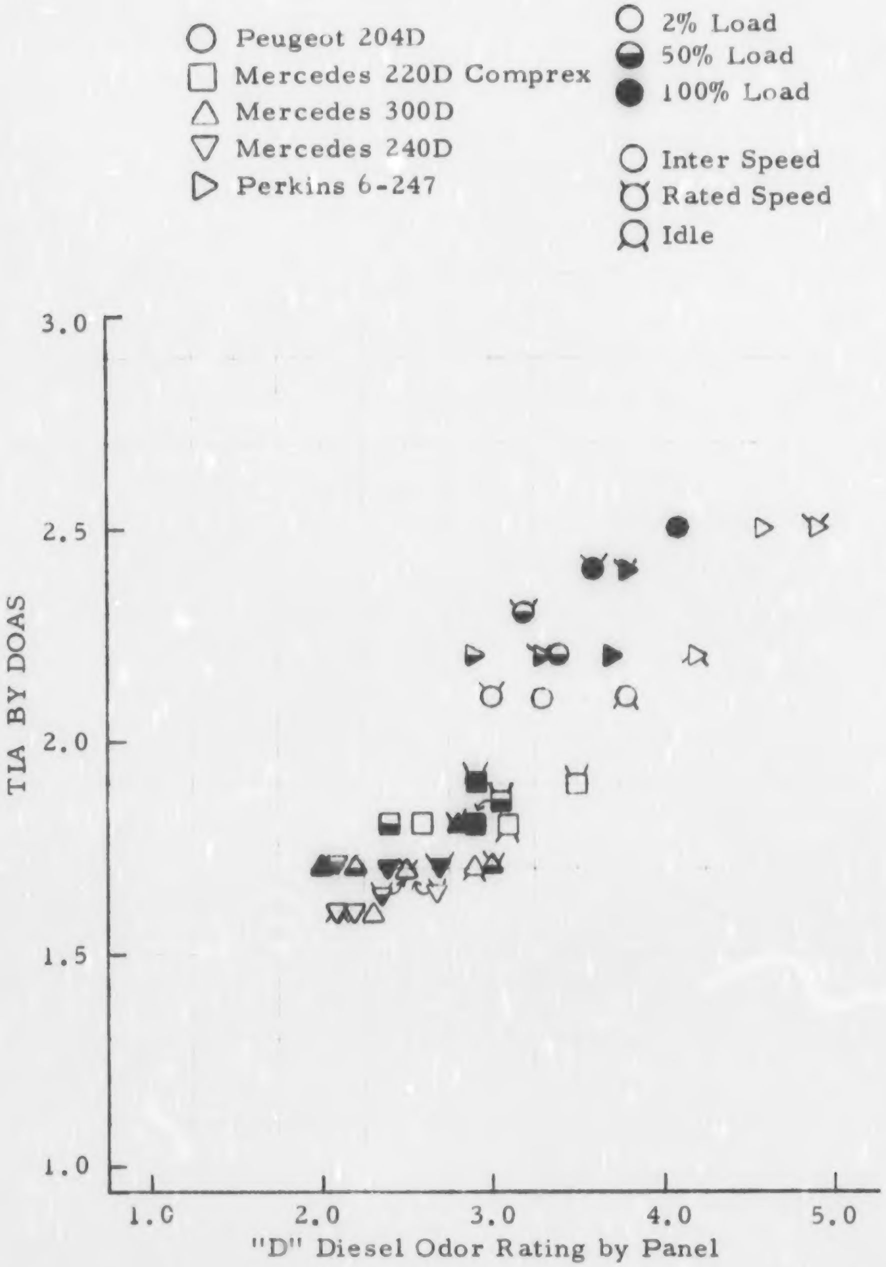


FIGURE 52. TIA BY DOAS VERSUS "D" ODOR RATING BY TRAINED PANEL FOR FIVE LD DIESEL VEHICLES

## TABLE 37. DOAS RESULTS DURING VARIOUS TRANSIENT CYCLES
(Five Diesel Powered LDV'S)

| | | | DOAS Results | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Run | LCA, μg/l | | | LCO, μg/l | | | TIA | | |
| Vehicle | Test Date | No. | FTP | FET | SET | FTP | FET | SET | FTP | FET | SET |
| Mercedes | 11-21-75 | 1 | 3.25 | 4.92 | 3.69 | 0.98 | 1.68 | 1.13 | 0.99 | 1.23 | 1.06 |
| 220D | 11-24-75 | 2 | 2.71 | 6.80 | 3.81 | 1.01 | 2.77 | 1.35 | 1.00 | 1.44 | 1.14 |
| Comprex | 11-25-75 | 3 | 3.35 | 6.84 | 4.09 | 1.29 | 2.93 | 1.45 | 1.11 | 1.47 | 1.16 |
| | Average | | 3.10 | 6.19 | 3.86 | 1.09 | 2.46 | 1.31 | 1.03 | 1.38 | 1.12 |
| Mercedes | 11-12-75 | 1 | 1.74 | ---- | 2.25 | 0.87 | 1.48 | 1.29 | 0.94 | 1.32 | 1.11 |
| 240D | 11-13-75 | 2 | 1.42 | 1.79 | 1.42 | 0.75 | 1.22 | 0.75 | 0.88 | 1.09 | 0.88 |
| | 11-14-75 | 3 | 1.57 | 1.91 | 1.69 | 0.72 | 1.13 | 0.83 | 0.86 | 1.06 | 0.92 |
| | Average | | 1.58 | 1.80 | 1.79 | 0.78 | 1.28 | 0.96 | 0.89 | 1.16 | 0.97 |
| Mercedes | 11-12-75 | 1 | 1.49 | 2.92 | 1.61 | 0.72 | 1.47 | 0.76 | 0.86 | 1.17 | 0.88 |
| 300D | 11-13-75 | 2 | 1.50 | 2.02 | 1.40 | 0.82 | 1.17 | 0.79 | 0.90 | 1.07 | 0.90 |
| | 11-14-75 | 3 | 1.31 | 1.86 | 1.35 | 0.66 | 1.35 | 1.20 | 0.82 | 1.13 | 0.88 |
| | Average | | 1.43 | 2.27 | 1.45 | 0.73 | 1.33 | 0.92 | 0.86 | 1.12 | 0.89 |
| Peugeot | 11-21-75 | 1 | 5.33 | 10.97 | 9.60 | 1.93 | 4.40 | 3.80 | 1.29 | 1.65 | 1.58 |
| 204D | 11-24-75 | 2 | 6.09 | 12.94 | 11.31 | 2.33 | 5.17 | 4.24 | 1.37 | 1.71 | 1.63 |
| | 11-25-75 | 3 | 7.23 | ---- | 10.66 | 2.93 | 6.73 | 4.31 | 1.47 | 1.83 | 1.64 |
| | Average | | 6.22 | 11.96 | 10.52 | 2.40 | 5.43 | 4.12 | 1.38 | 1.73 | 1.62 |
| Perkins | 11-21-75 | 1 | 4.81 | 15.52 | 9.27 | 2.30 | 7.90 | 4.42 | 1.36 | 1.90 | 1.65 |
| 6-247 | 11-24-75 | 2 | 4.36 | 15.57 | 8.16 | 2.28 | 7.60 | 3.71 | 1.36 | 1.88 | 1.57 |
| | 11-25-75 | 3 | 4.55 | 14.33 | 8.69 | 2.33 | 7.07 | 4.02 | 1.37 | 1.85 | 1.61 |
| | Average | | 4.57 | 15.14 | 8.71 | 2.30 | 7.52 | 4.05 | 1.36 | 1.88 | 1.61 |

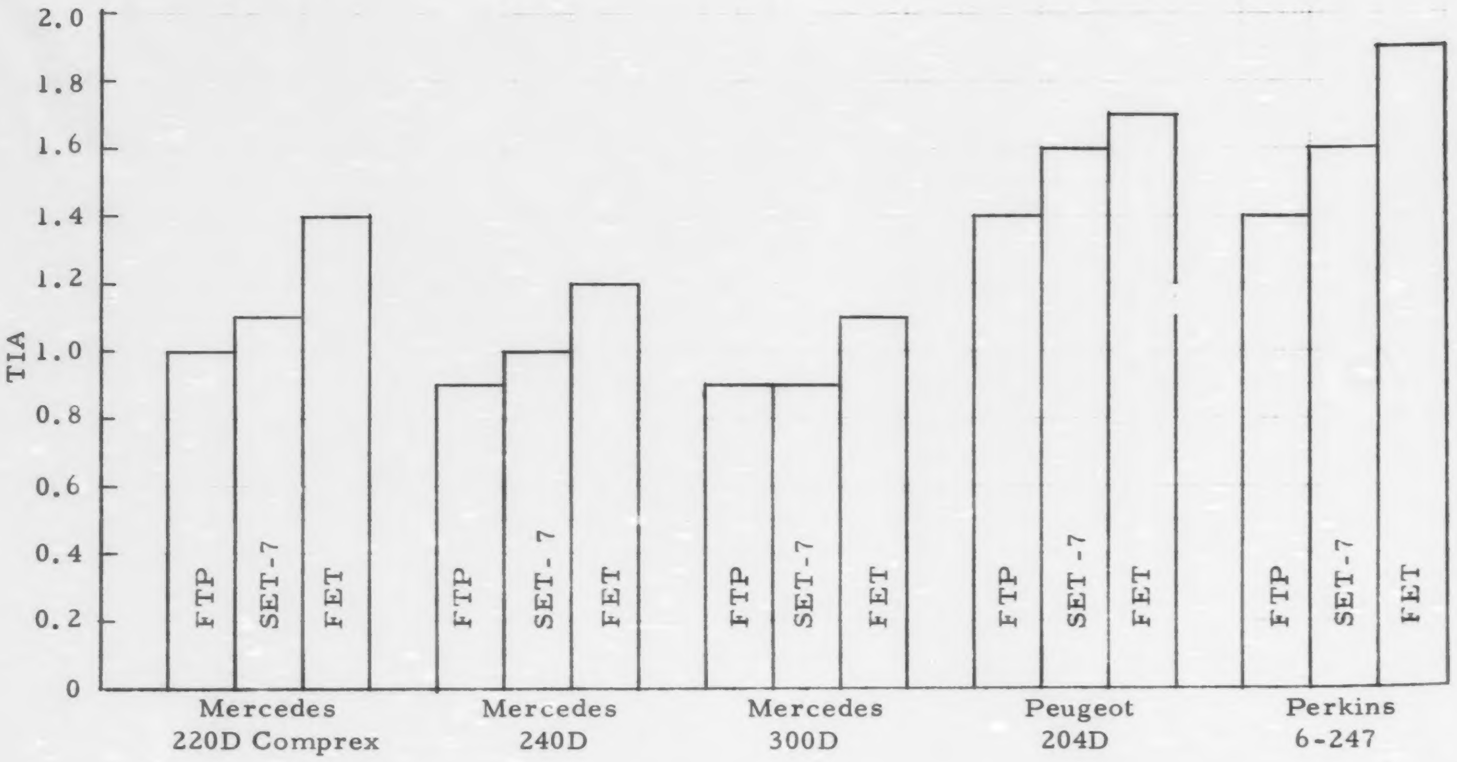


FIGURE 53. SUMMARY OF FTP, SET-7 AND FET RESULTS

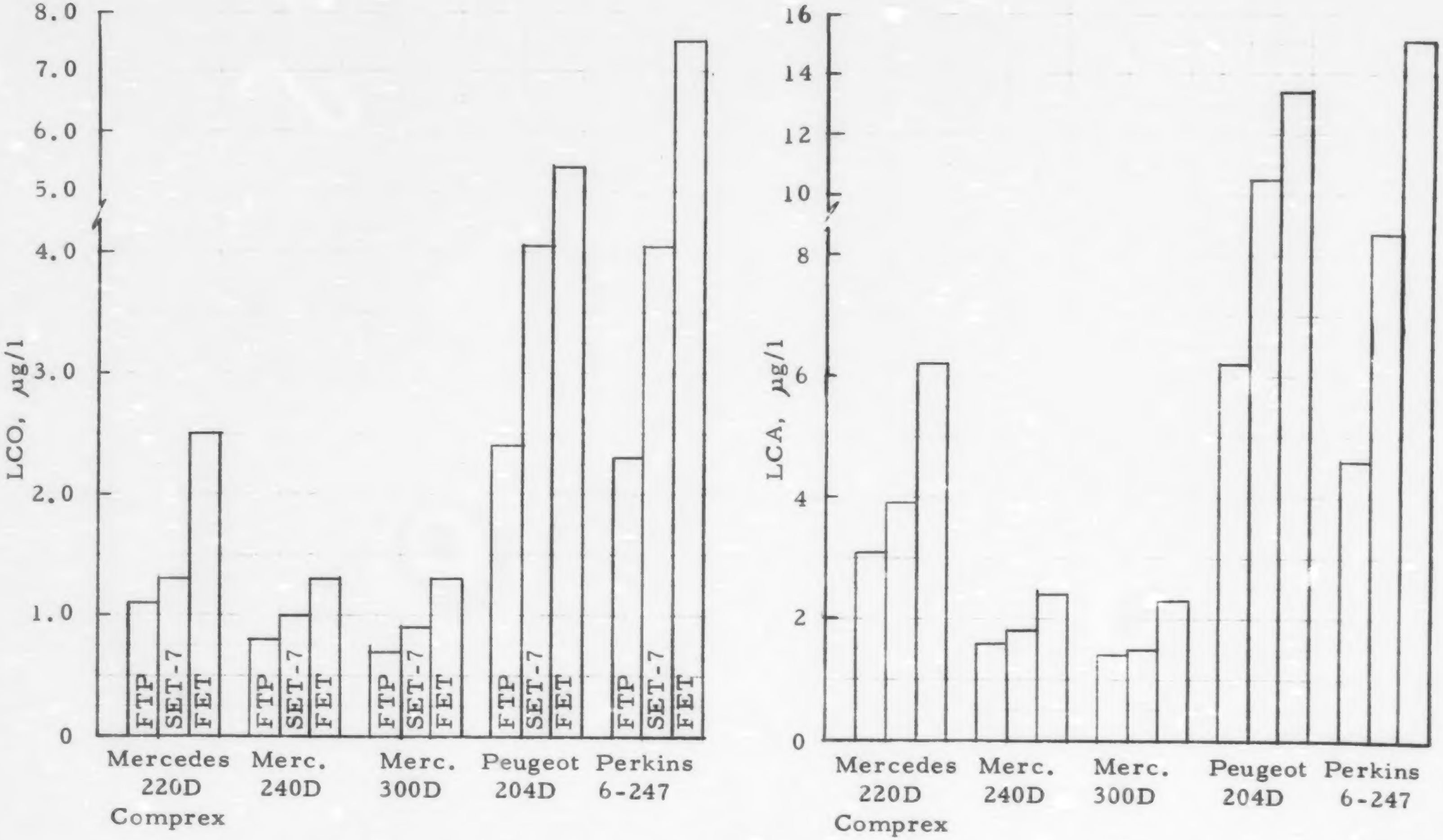


FIGURE 53 (Cont'd.) SUMMARY OF FTP, SET-7 AND FET RESULTS

### 5. Detailed Hydrocarbons

The detailed exhaust hydrocarbons, most of which are considered to be non-reactive, were analyzed during both steady state and transient vehicle operation.

#### a. Simultaneous with Odor Panel

Summarized on Table 38 are the results of the detailed HC analysis from samples collected during the seven steady state odor test conditions. A single sample was analyzed in each case and all results have been corrected for background hydrocarbon content.

Methane and ethylene, generally the two most predominant hydrocarbons, were quite similar for the Mercedes 240D and 300D cars, as would be expected. The Peugeot 204D and Perkins 6-247 exhaust analysis revealed substantially higher methane and ethylene as well as ethane, acetylene, propane, propylene, benzene and toluene. There were some exceptions to this comparison but as a general rule, these two vehicles had much more of most of the individual hydrocarbons.

In some instances, the Comprex equipped Mercedes 220D had higher methane and/or ethylene such as 100 percent load at intermediate speed and high speed, 2 percent load. Overall, the Mercedes 220D Comprex HC analyses were similar to the other two Mercedes cars.

It is possible to use the concentration data listed in Table 39, the fuel rate data listed in Table 5 of Section III, and the average air flow data listed in the data tabulations in Appendix K to compute emission rates of methane, ethylene, etc., in terms of g/hr or g/kg fuel consumed.

#### b. Transient Cycles

The results of the HC analysis of samples collected during the three driving cycles are tabulated on Table 39 in terms of concentration and g/km. Since the concentration data, of necessity, is of the CVS air diluted exhaust and not raw exhaust, the concentrations cannot be easily or directly compared even for the three Mercedes cars since the exhaust volume was variable. For example, the Peugeot 204D concentrations are much more dilute than the Perkins 6-247 due to the engine displacement and exhaust flow difference.

To enable some measure of comparison on a common basis, the emission rate was computed for each hydrocarbon in terms of mg/km.

### TABLE 38. DETAILED HYDROCARBON ANALYSIS OF SAMPLES TAKEN DURING STEADY-STATE ODOR TESTS

| Vehicle Condition | Exhaust Emissions | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|---|
| Intermediate Speed, 2% Load | Methane, ppmC | 6.1 | 4.5 | 4.1 | 6.4 | 10.9 |
| | Ethylene, ppmC | 12.3 | 11.0 | 8.1 | 29.9 | 60.5 |
| | Ethane, ppmC | 0.9 | 0.5 | 0.3 | 0.9 | 1.7 |
| | Acetylene, ppmC | 2.2 | 1.7 | 1.3 | 3.8 | 7.1 |
| | Propane, ppmC | 0.1 | 0.1 | tr * | 0.3 | 0.2 |
| | Propylene, ppmC | 3.3 | 3.4 | 2.3 | 10.6 | 21.7 |
| | Benzene, ppmC | 1.9 | 1.5 | 2.0 | 4.5 | 5.0 |
| | Toluene, ppmC | 0.2 | 0.1 | 0.6 | 1.4 | 1.9 |
| Intermediate Speed, 50% Load | Methane, ppmC | 3.6 | 3.1 | 3.9 | 7.0 | 13.7 |
| | Ethylene, ppmC | 3.2 | 7.9 | 8.7 | 34.6 | 28.0 |
| | Ethane, ppmC | 0.2 | 0.3 | 0.4 | 1.6 | 0.9 |
| | Acetylene, ppmC | 0.7 | 1.0 | 1.2 | 4.4 | 9.1 |
| | Propane, ppmC | tr* | 0.1 | tr* | 0.5 | tr * |
| | Propylene, ppmC | 0.7 | 2.4 | 2.5 | 13.6 | 6.2 |
| | Benzene, ppmC | 1.2 | 1.9 | 2.0 | 4.2 | 8.0 |
| | Toluene, ppmC | 0.2 | 0.4 | 0.4 | 1.5 | 0.8 |
| Intermediate Speed, 100% Load | Methane, ppmC | 10.6 | 3.5 | 3.2 | 16.1 | 126.0 |
| | Ethylene, ppmC | 3.6 | 5.9 | 6.5 | 78.1 | 83.6 |
| | Ethane, ppmC | 0.2 | 0.1 | 0.3 | 4.4 | 4.5 |
| | Acetylene, ppmC | 1.9 | 1.1 | 0.9 | 9.4 | 66.9 |
| | Propane, ppmC | tr * | 0.0 | tr* | 0.8 | 0.3 |
| | Propylene, ppmC | 0.4 | 1.4 | 1.7 | 34.0 | 7.0 |
| | Benzene, ppmC | 2.0 | 1.7 | 1.3 | 2.0 | 25.7 |
| | Toluene, ppmC | 0.2 | 0.1 | 0.2 | 0.0 | 1.1 |
| High Speed, 2% Load | Methane, ppmC | 21.7 | 6.6 | 5.8 | 7.9 | 12.7 |
| | Ethylene, ppmC | 32.6 | 10.9 | 9.3 | 32.3 | 69.0 |
| | Ethane, ppmC | 2.2 | 0.6 | 0.5 | 1.0 | 2.3 |
| | Acetylene, ppmC | 8.4 | 2.6 | 1.7 | 4.8 | 7.9 |
| | Propane, ppmC | 0.3 | tr * | tr * | 0.1 | 0.3 |
| | Propylene, ppmC | 7.7 | 2.9 | 2.2 | 9.0 | 25.9 |
| | Benzene, ppmC | 10.9 | 2.4 | 2.8 | 4.8 | 3.2 |
| | Toluene, ppmC | 2.9 | 0.3 | 0.7 | 1.0 | 1.6 |
| High Speed, 50 % Load | Methane, ppmC | 6.7 | 3.1 | 3.5 | 5.5 | 8.6 |
| | Ethylene, ppmC | 7.1 | 5.3 | 5.4 | 32.8 | 18.4 |
| | Ethane, ppmC | 0.5 | 0.2 | 0.3 | 1.1 | 0.5 |
| | Acetylene, ppmC | 1.4 | 1.3 | 1.1 | 3.4 | 6.0 |
| | Propane, ppmC | 0.1 | 0.0 | tr * | 0.3 | 0.0 |
| | Propylene, ppmC | 1.7 | 1.3 | 1.1 | 11.7 | 3.9 |
| | Benzene, ppmC | 1.2 | 1.7 | 0.9 | 4.2 | 4.1 |
| | Toluene, ppmC | 0.2 | 0.1 | 0.3 | 3.3 | 0.6 |
| High Speed, 100% Load | Methane, ppmC | 1.7 | 3.3 | 3.2 | 7.2 | 90.1 |
| | Ethylene, ppmC | 1.1 | 5.7 | 4.5 | 56.2 | 111.8 |
| | Ethane, ppmC | tr * | 0.1 | 0.2 | 2.2 | 4.1 |
| | Acetylene, ppmC | 0.3 | 1.5 | 1.1 | 5.0 | 60.7 |
| | Propane, ppmC | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 |
| | Propylene, ppmC | 0.4 | 0.9 | 1.0 | 23.8 | 7.7 |
| | Benzene, ppmC | 0.6 | 1.4 | 1.2 | 8.5 | 21.0 |
| | Toluene, ppmC | tr * | tr * | 0.2 | 1.8 | 0.6 |
| Idle | Methane, ppmC | 5.2 | 5.6 | 4.8 | 9.6 | 5.2 |
| | Ethylene, ppmC | 12.8 | 12.7 | 10.1 | 45.9 | 21.8 |
| | Ethane, ppmC | 0.8 | 0.8 | 0.6 | 1.9 | 0.3 |
| | Acetylene, ppmC | 2.0 | 2.0 | 1.6 | 6.0 | 2.1 |
| | Propane, ppmC | 0.2 | 0.1 | 0.1 | 0.4 | tr * |
| | Propylene, ppmC | 3.7 | 4.0 | 3.2 | 17.7 | 7.8 |
| | Benzene, ppmC | 3.2 | 1.9 | 2.9 | 2.2 | 3.0 |
| | Toluene, ppmC | 0.7 | 0.4 | 0.8 | 1.1 | 0.7 |

*trace, less than 0.1 ppmC

TABLE 39. DETAILED HYDROCARBON ANALYSIS OF SAMPLES TAKEN DURING VARIOUS TRANSIENT CYCLES

| Emission | Units[1] | Test | Bag | Mercedes 220D Comp. | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|---|---|---|
| Methane | ppmC | FTP | 1 | 2.5 | 0.9 | 0.5 | 1.7 | 4.8 |
| | | | 2 | 2.0 | 0.3 | 0.1 | 0.6 | 2.1 |
| | | | 3 | 2.5 | 0.6 | 0.5 | 1.7 | 3.1 |
| | | SET | | 4.8 | 2.7 | 2.7 | 2.2 | 4.5 |
| | | FET | | 5.5 | 3.1 | 3.1 | 2.4 | 5.9 |
| | mg/km | FTP | | 19.65 | 5.57 | 3.94 | 9.30 | 24.48 |
| | | SET | | 13.82 | 2.75 | 3.34 | 4.44 | 13.58 |
| | | FET | | 12.58 | 3.66 | 4.25 | 4.04 | 14.96 |
| Ethylene | ppmC | FTP | 1 | 3.7 | 3.4 | 2.4 | 7.1 | 10.1 |
| | | | 2 | 2.7 | 1.9 | 1.7 | 4.2 | 5.6 |
| | | | 3 | 3.1 | 3.1 | 2.0 | 6.4 | 8.5 |
| | | SET | | 3.7 | 2.9 | 2.2 | 6.6 | 13.1 |
| | | FET | | 4.9 | 4.0 | 2.7 | 8.0 | 19.1 |
| | mg/km | FTP | | 21.63 | 17.74 | 14.49 | 38.13 | 91.31 |
| | | SET | | 15.26 | 12.07 | 9.39 | 27.76 | 54.75 |
| | | FET | | 14.56 | 12.14 | 8.49 | 24.20 | 60.16 |
| Ethane | ppmC | FTP | 1 | tr.[2] | tr. | tr. | tr. | tr. |
| | | | 2 | tr. | 0.0 | tr. | tr. | tr. |
| | | | 3 | tr. | 0.0 | tr. | tr. | tr. |
| | | SET | | tr. | 0.0 | tr. | tr. | tr. |
| | | FET | | tr. | 0.0 | tr. | tr. | 0.7 |
| | mg/km | FTP | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | SET | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | FET | | 0.0 | 0.0 | 0.0 | 0.0 | 4.07 |
| Acetylene | ppmC | FTP | 1 | 1.5 | 1.2 | 1.0 | 1.6 | 3.7 |
| | | | 2 | 1.2 | tr. | tr. | 0.9 | 1.6 |
| | | | 3 | 1.3 | tr. | 1.1 | 1.3 | 2.7 |
| | | SET | | 1.7 | 1.3 | tr. | 1.3 | 3.1 |
| | | FET | | 2.2 | 1.4 | 1.2 | 1.7 | 4.6 |
| | mg/km | FTP | | 8.65 | 1.31 | 2.81 | 7.57 | 14.89 |
| | | SET | | 6.51 | 5.02 | tr. | 5.08 | 6.59 |
| | | FET | | 6.07 | 8.94 | 3.50 | 4.77 | 12.91 |
| Propane | ppmC | FTP | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | SET | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | FET | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | mg/km | FTP | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | SET | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | FET | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Propylene | ppmC | FTP | 1 | tr. | tr. | tr. | 2.6 | 3.4 |
| | | | 2 | tr. | tr. | 0.0 | 2.8 | 1.9 |
| | | | 3 | tr. | tr. | 0.0 | 2.4 | 3.0 |
| | | SET | | tr. | tr. | 0.0 | 2.6 | 4.5 |
| | | FET | | tr. | tr. | tr. | 2.1 | 7.3 |
| | mg/km | FTP | | 0.0 | 0.0 | 0.0 | 19.98 | 17.55 |
| | | SET | | 0.0 | 0.0 | 0.0 | 10.93 | 18.80 |
| | | FET | | 0.0 | 0.0 | 0.0 | 9.37 | 21.67 |
| Benzene | ppmC | FTP | 1 | 2.9 | tr. | 0.6 | tr. | 1.6 |
| | | | 2 | tr. | 0.0 | 0.0 | tr. | 1.2 |
| | | | 3 | 1.8 | tr. | 1.1 | tr. | 1.4 |
| | | SET | | 0.8 | tr. | tr. | tr. | 1.8 |
| | | FET | | 1.7 | tr. | 1.0 | tr. | 2.4 |
| | mg/km | FTP | | 6.07 | 0.0 | 2.51 | 0.0 | 9.56 |
| | | SET | | 3.26 | 0.0 | 0.0 | 0.0 | 9.90 |
| | | FET | | 4.99 | 0.0 | 3.10 | 0.0 | 5.28 |
| Toluene | ppmC | FTP | 1 | 0.0 | 0.0 | 0.0 | 0.0 | tr. |
| | | | 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | 3 | 0.0 | 0.0 | 0.0 | 0.0 | tr. |
| | | SET | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | FET | | 0.0 | 0.0 | 0.0 | 0.0 | tr. |
| | mg/km | FTP | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | SET | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | FET | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

(1) air diluted CVS sampler concentration
(2) trace means ≤ .05 ppm or ≤ 0.15 mg/km

It is interesting to look at the effect of driving cycle on the emission rate as well as the car make/model for each hydrocarbon. In some cases, such as methane and ethylene, the greater the average speed and duty cycle, the lower the mg/km. The other hydrocarbons were all in the trace to very low ppm, making these g/km values extremely low. In the case of trace concentrations, $<0.05$ ppm, the mg/km values were assigned zero.

As with the heavy duty diesels, the methane fraction of the exhaust hydrocarbons is very low, almost negligible. For additional analyses, the mg/km methane values may be compared to the FID-HC g/km values listed earlier on Table 23. For example, the Mercedes 240D 1975 FTP HC rate was 0.18 g/km or 180 mg/km. The same vehicle, same test procedure yielded 5.57 mg/km of methane.

### 6. Aldehydes

The DNPH method was used to measure a variety of aldehydes in the exhaust of the five LD diesels. Measurements were made during the odor testing steady states as well as during various transient driving cycles.

#### a. Aldehydes - Simultaneous with Odor Panel

Table 40 is a listing of the various aldehyde concentrations obtained during the seven steady state conditions. Recall that the three replicate runs made on a given day for each of the seven conditions were accumulated in a single wet collector. Thus each value shown is based on a single composite observation considered representative of what the odor panel and other emission measurements were made from.

The most important observation from Table 40 is the substantial, about 8 to 40 fold higher formaldehyde values for the Peugeot 204D relative to the other three passenger cars. In many instances, the Perkins 6-247 engine matched the Peugeot 204D such as during the 2 percent intermediate speed and high speed conditions and almost during the idle. While all three Mercedes cars had essentially identical aldehydes under practically all test conditions, the Peugeot 204D and to a lesser extent the Perkins 6-247 had much higher acetaldehyde, acetone, isobutanal, crotanal, hexanal, and benzaldehyde. The differences in the various aldehydes relative to the Mercedes diesel may explain why the odor from both the Peugeot 204D and Perkins 6-247 was higher as well as differences in particulate and is consistent with other differences and trends already discussed.

#### b. Aldehydes - Transient Cycles

Table 41 has both concentration and mass emission rate in mg per km for each car, each driving cycle and each of the various aldehydes analyzed. The wet collector served to integrate the exhaust sample throughout each test cycle. As with the NRHC, the dilute concentration values are not as informative as the mg/km calculated emission rates.

## TABLE 40. ALDEHYDES FROM FIVE LD DIESEL VEHICLES OBTAINED DURING STEADY-STATE ODOR TEST

(all values in $\mu g/m^3$)

| Condition | Aldehyde | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|---|
| Intermediate Speed, 2% Power | Formaldehyde | 1341 | 1553 | 1624 | 29087 | 26404 |
| | Acetaldehyde | 635 | 883 | 530 | 8825 | 11014 |
| | Acetone | 565 | 1024 | 6 | 5295 | 8225 |
| | Isobutanal | 353 | 2930 | 0 | 530 | 6495 |
| | Crotonal | 530 | 812 | 0 | 918 | 4942 |
| | Hexanal | 106 | 494 | 0 | 282 | 2859 |
| | Benzaldehyde | 0 | 0 | 0 | 212 | 3495 |
| Intermediate Speed, 50% Power | Formaldehyde | 353 | 459 | 459 | 15461 | 2789 |
| | Acetaldehyde | 212 | 530 | 106 | 5825 | 1447 |
| | Acetone | 106 | 530 | 35 | 6495 | 706 |
| | Isobutanal | 0 | 1483 | 0 | 2542 | 2965 |
| | Crotonal | 318 | 353 | 212 | 212 | 0 |
| | Hexanal | 177 | 247 | 71 | 353 | 388 |
| | Benzaldehyde | 0 | 0 | 0 | 635 | 494 |
| Intermediate Speed, 100% Power | Formaldehyde | 530 | 459 | 353 | 13273 | 5436 |
| | Acetaldehyde | 177 | 706 | 106 | 6425 | 1236 |
| | Acetone | 106 | 847 | 0 | 3883 | 282 |
| | Isobutanal | 0 | 1341 | 0 | ---- | 1094 |
| | Crotonal | 565 | 318 | 212 | 635 | 812 |
| | Hexanal | 212 | 318 | 0 | 353 | 671 |
| | Benzaldehyde | 0 | 212 | 0 | 1624 | 1694 |
| High Speed, 2% Power | Formaldehyde | 4060 | 1165 | 812 | 24569 | 18144 |
| | Acetaldehyde | 1412 | 494 | 424 | 9637 | 7095 |
| | Acetone | 353 | 424 | 353 | 6036 | 3495 |
| | Isobutanal | 0 | 1200 | 141 | 741 | 2542 |
| | Crotonal | 353 | 530 | 706 | 1694 | 1059 |
| | Hexanal | 177 | 600 | 71 | 2118 | 812 |
| | Benzaldehyde | 177 | 0 | 2648 | 0 | 953 |
| High Speed, 50% Power | Formaldehyde | 530 | 494 | 459 | 14297 | 1694 |
| | Acetaldehyde | 353 | 530 | 212 | 4589 | 883 |
| | Acetone | 318 | 671 | 35 | 4060 | 459 |
| | Isobutanal | 388 | 1800 | 0 | 883 | 1659 |
| | Crotonal | 706 | 635 | 318 | 212 | 424 |
| | Hexanal | 71 | 671 | 106 | 565 | 177 |
| | Benzaldehyde | 0 | 0 | 0 | 141 | 530 |
| High Speed, 100% Power | Formaldehyde | 459 | 459 | 1236 | 21639 | 7600 |
| | Acetaldehyde | 177 | 459 | 671 | 6425 | 2083 |
| | Acetone | 106 | 353 | 106 | 6649 | 459 |
| | Isobutanal | 0 | 918 | 318 | | 635 |
| | Cortonal | 953 | 671 | 635 | 777 | 318 |
| | Hexanal | 106 | 530 | 212 | 353 | 177 |
| | Benzaldehyde | 0 | 353 | 1553 | 1165 | 2118 |
| Idle Speed No Power | Formaldehyde | 2330 | 2542 | 2153 | 41901 | 24604 |
| | Acetaldehyde | 1059 | 1271 | 847 | 13308 | 8154 |
| | Acetone | 530 | 1306 | 388 | 12884 | 7201 |
| | Isobutanal | 0 | 3001 | 388 | 1236 | 5825 |
| | Crotonal | 530 | 635 | 671 | 2365 | 1836 |
| | Hexanal | 353 | 177 | 106 | 5154 | 1836 |
| | Benzaldehyde | 0 | 0 | 0 | 0 | 565 |

## TABLE 41. ALDEHYDES FROM FIVE LD DIESEL VEHICLES OPERATED OVER VARIOUS TRANSIENT DRIVING CYCLES

| Aldehyde | Cycle | Units | Mercedes 220D Comprex | Mercedes 240D | Mercedes 300D | Peugeot 204D | Perkins 6-247 |
|---|---|---|---|---|---|---|---|
| Formaldehyde | FTP | $\mu g/m^{3*}$ | 214 | 337 | 323 | 956 | 3244 |
| | | mg/km | 2.52 | 3.96 | 3.80 | 11.25 | 38.17 |
| | SET | $\mu g/m^3$ | 210 | 432 | 829 | 1192 | 1459 |
| | | mg/km | 1.50 | 3.08 | 5.81 | 8.50 | 10.4 |
| | FET | $\mu g/m^3$ | 301 | 692 | 766 | 1505 | 5332 |
| | | mg/km | 1.55 | 3.57 | 3.95 | 7.76 | 27.5 |
| Acetaldehyde | FTP | $\mu g/m^3$ | 85 | 96 | 94 | 364 | 893 |
| | | mg/km | 1.00 | 1.13 | 1.11 | 4.28 | 10.50 |
| | SET | $\mu g/m^3$ | 0 | 77 | 0 | 526 | 1368 |
| | | mg/km | 0 | 0.55 | 0 | 3.75 | 9.75 |
| | FET | $\mu g/m^3$ | 0 | 231 | 0 | 785 | 551 |
| | | mg/km | 0 | 1.19 | 0 | 4.05 | 2.84 |
| Acetone | FTP | $\mu g/m^3$ | 712 | 125 | 800 | 256 | 451 |
| | | mg/km | 8.37 | 1.47 | 9.41 | 3.01 | 5.31 |
| | SET | $\mu g/m^3$ | 1424 | 419 | 916 | 222 | 1736 |
| | | mg/km | 10.15 | 2.99 | 6.53 | 1.58 | 12.38 |
| | FET | $\mu g/m^3$ | 836 | 477 | 281 | 894 | 2088 |
| | | mg/km | 4.31 | 2.46 | 1.45 | 4.61 | 10.77 |
| Iso-butanal | FTP | $\mu g/m^3$ | 942 | 186 | 0 | 744 | 1105 |
| | | mg/km | 11.08 | 2.19 | 0 | 8.75 | 13.0 |
| | SET | $\mu g/m^3$ | 2239 | 502 | 0 | 917 | 2378 |
| | | mg/km | 15.96 | 3.58 | 0 | 6.54 | 16.95 |
| | FET | $\mu g/m^3$ | 1532 | 826 | 291 | 1536 | 1446 |
| | | mg/km | 7.90 | 4.26 | 1.50 | 7.92 | 7.46 |
| Crotonal | FTP | $\mu g/m^3$ | 201 | 57 | 99 | 349 | 428 |
| | | mg/km | 2.37 | 0.67 | 1.17 | 4.10 | 5.04 |
| | SET | $\mu g/m^3$ | 396 | 318 | 164 | 386 | 383 |
| | | mg/km | 2.82 | 2.27 | 1.17 | 2.75 | 2.73 |
| | FET | $\mu g/m^3$ | 339 | 293 | 0 | 611 | 1357 |
| | | mg/km | 1.75 | 1.51 | 0 | 3.05 | 7.00 |
| Hexanal | FTP | $\mu g/m^3$ | 40 | 0 | 0 | 0 | 0 |
| | | mg/km | 0.47 | 0 | 0 | 0 | 0 |
| | SET | $\mu g/m^3$ | 254 | 18 | 0 | 0 | 226 |
| | | mg/km | 1.81 | 0.13 | 0 | 0 | 1.61 |
| | FET | $\mu g/m^3$ | 301 | 130 | 87 | 0 | 165 |
| | | mg/km | 1.55 | 0.67 | 0.45 | 0 | 0.85 |
| Benzaldehyde | FTP | $\mu g/m^3$ | 0 | 0 | 0 | 0 | 500 |
| | | mg/km | 0 | 0 | 0 | 0 | 5.88 |
| | SET | $\mu g/m^3$ | 0 | 321 | 0 | 0 | 0 |
| | | mg/km | 0 | 2.29 | 0 | 0 | 0 |
| | FET | $\mu g/m^3$ | 0 | 388 | 237 | 0 | 215 |
| | | mg/km | 0 | 2.00 | 1.22 | 0 | 1.11 |

*CVS - diluted sample

It is interesting to note the generally consistent formaldehyde and acetaldehyde values of the three Mercedes cars, regardless of test cycle, while the Peugeot 204D and Perkins 6-247 were quite substantially higher. The Perkins, under most tests was even higher than the Peugeot. Quite variable results were noted for acetone, isobutanal, crotonal. In many instances, no hexanal or benzaldehyde was measured.

The Mercedes 240D tended to have lowest FTP acetone and crotonal. For many of the aldehydes measured, the results were inconsistent for the Mercedes 240D and 300D. This is contrary to what might have been expected since the two engines are very similar except for number of cylinders. This was the first attempt to measure aldehydes by the DNPH method from diesel cars during transient driving via dilute CVS exhaust sampling. Repeatability and precision of the aldehyde analyses presented has not been qualified at this writing.

Most important from Table 41 and the aldehyde measurements is the apparent substantially higher formaldehyde and acetaldehyde rates from the two most odorous, highest hydrocarbon vehicles tested, the Peugeot 204D and Perkins 6-247.

## E. Vehicle Noise and Performance

The final areas of evaluation of the five diesel powered vehicles involved noise and acceleration performance measurements.

### 1. Noise Results

Table 42 is a summary of all the vehicle noise measurements made. For more complete, individual run sound level measurements, please refer to Appendix L. Please note that for the Perkins 6-247 powered I-H pick-up truck, the accelerations were made in third instead of second gear with the four speed manual transmission. First gear is rarely used in everyday driving.

With the Mercedes 220 Comprex and 240 diesel cars, a resonant, low frequency noise was noted inside each car at or near a constant speed of 48.3 km/hr. On the 220 Comprex, the rather strong resonant sound occurred at very slight acceleration from constant 48.3 km/hr while in the 240 model, the particular sound was prominent during constant 48.3 km/hr. The intensity and character of the noise in the Mercedes 240D was noticeably moderated at deceleration from 51.5 to 48.3 km/hr.

All four passenger cars may be termed "quiet" in terms of the SAE J986 exterior drive-by ranging from 70.5 to 72.5 dBA. The same is true during the exterior drive-by at 48.3 km/hr. The Peugeot 204D was slightly above the other three cars at 63 dBA versus 59 to 59.8 dBA.

## TABLE 42. SUMMARY OF SOUND LEVEL MEASUREMENTS FOR FIVE DIESEL POWERED LIGHT DUTY VEHICLES - dBA SCALE

| | Mercedes 220D Comp. | Mercedes 240D | Peugeot 204 | Mercedes 300D | Perkins 6-247 |
|---|---|---|---|---|---|
| Date Tested | 7-8-75 | 7-9-75 | 7-9-75 | 7-28-75 | 2-2-76 |
| SAE J986a Accel Driveby | | | | | |
| Exterior | 71.5 | 70.5 | 72.5 | 71.8 | 79(3) |
| Interior | | | | | |
| Blower On (1) | 82.5 | 78.5 | 80 | 79 | 80.5(3) |
| Off | 77.8 | 75 | 79.8 | 76.5 | 80.3(3) |
| 48.3 km/hr Driveby | | | | | |
| Exterior | 59 | 59.8 | 63 | 59.5 | 65 |
| Interior | | | | | |
| Blower On(1) | 78 | 81 | 71.8 | 75.8 | 72.3 |
| Off | 73.8 | 80.8 | 69.5 | 63.8 | 70.5 |
| Engine Idle | | | | | |
| Exterior(2) | 67.5 | 65.5 | 69.5 | 67 | 72.5 |
| Interior | | | | | |
| Blower On(1) | 75.5 | 70.5 | 67.5 | 68.5 | 66 |
| Off | 54.8 | 53.5 | 58 | 54.5 | 63.5 |

(1)Windows Up, Fresh Air Blower on High
(2)At 3.05 m
(3)Accel in 3rd gear

As would be expected, the Mercedes 240D and 300D gave almost identical sound levels. Apparently the 5 cylinder engine has little influence on the vehicle noise. Slightly higher levels were found during the acceleration and exterior idle.

The interior measurements were greatly influenced by whether or not the air circulating blower was on (in its "high" position) or not. This blower continues to dominate the measured noise level inside the vehicle. The Peugeot 204D interior acceleration driveby seemed the least affected by the blower. In all, the four diesel passenger cars had low noise levels, confirming that which is obvious to those who own or drive these cars.

The Perkins 6-247 powered IH pick-up truck does not compare with the four diesel passenger cars. All exterior noise measurements were higher than the four passenger cars. The Perkins powered truck was on the order of 7 dBA higher during the SAE driveby acceleration, 3 dBA higher during the 48.3 km/hr cruise and about 5 dBA higher during idle. Interior measurements were not all that different from the four cars. The one exception was the interior rating, blower off and during the SAE driveby.

A direct comparison of the Perkins pick-up to the other four passenger cars is not justified since the Perkins engine was merely installed in an existing pick-up truck and no attempt made to develop a total vehicle as has been the case with the automobiles. The noise levels, though comparable to gasoline powered passenger cars in dBA intensity can, under certain conditions such as idle, have a definitely different noise quality. One example was the Comprex equipped Mercedes 220D car which had a distinctive high pitch whine similar to the sound of a vacuum cleaner. The whine, though noticeable, was not considered objectionable or annoying.

### 2. Performance Results

Although not required by the project, it was felt that some limited information on vehicle acceleration performance might be of value. Therefore, at the conclusion of the project, acceleration times were obtained both directions over a level road course. The results of these tests made to determine time to go from 0 to 96.5 km/hr (0-60 mph), 0-64.4 km/hr (0-40 mph) and 32.2-96.5 km/hr (20-60) were obtained.

Table 43 lists the average of three separate accelerations in each direction for the five vehicles. The 1556 kg Mercedes 220D equipped with the Comprex gave the best acceleration performance of the three medium size passenger cars. Others with the same weight, size and shape to the 220D are the Mercedes 240D (1497 kg) and 300D (1588 kg). The 220D size engine has the smallest displacement of the three. The Comprex makes the car perform better than the other two.

## TABLE 43. ACCELERATION TIMES FOR FIVE DIESEL POWERED LDV'S
(Windows up, air conditioner off)

| Vehicle | Direction | 0-64.4 km/hr(1) Time, Sec | 0-96.5 km/hr(2) Time, Sec | 32.2-96.5 km/hr(3) Time, Sec |
|---|---|---|---|---|
| Mercedes 220D Comprex | N | 8.9 | 17.5 | 15.0 |
| | S | 8.8 | 18.9 | 15.2 |
| | Average | 8.9 | 18.2 | 15.1 |
| Mercedes 240D | N | 13.4 | 26.2 | 23.5 |
| | S | 13.2 | 31.2 | 24.0 |
| | Average | 13.3 | 28.7 | 23.8 |
| Mercedes 300D | N | 10.8 | 22.7 | 19.6 |
| | S | 10.8 | 22.3 | 19.3 |
| | Average | 10.8 | 22.5 | 19.5 |
| Peugeot 204D | N | 14.3 | 35.0 | 29.5 |
| | S | 13.3 | 36.5 | 35.7 |
| | Average | 13.8 | 35.8 | 32.6 |
| Perkins 6-247 | N | 12.4 | 26.0 | 20.6 |
| | S | 12.1 | 26.6 | 21.5 |
| | Average | 12.3 | 26.3 | 21.1 |

---

(1) 0-40 mph
(2) 0-60 mph
(3) 20-60 mph

The 240D had a standard (manual) transmission, same as the 220D Comprex. The 300D was equipped with automatic transmission. The additional displacement (5 cylinders instead of 4) made the 300D outperform the 240D even though it was equipped with automatic transmission.

The Peugeot 204D, at 953 kg, was the lightest of the five vehicles. It also had the smallest diesel engine of the five. Its acceleration performance was somewhat poorer than the other three passenger cars during the 0-96.5 km/hr and 32.2-96.5 km/hr trials. The 0-64.4 km/hr accel time was about the same as the Mercedes 240D. Surprisingly, the Perkins 6-247, in a 1982 kg pick-up truck had acceleration times slightly better than the Mercedes 240D but not as good as the Mercedes 300D. Its ability to accelerate was far superior to the Peugeot 204D though twice the weight and with a larger, less aerodynamic frontal area.

The field trials shed some additional light on the ability of diesel powered light duty vehicles to perform. Wide open throttle accelerations such as those made in this series, are only one indicator of vehicle road performance. They do give a relative comparison, especially where factors of vehicle weight, transmission, power plant size and vehicle shape are considered.

## LIST OF REFERENCES

1. Springer, Karl J., "An Investigation of Diesel-Powered Vehicle Odor and Smoke - Part I," Final Report to the U. S. Public Health Service, Contract 86-66-93, March 1967.

2. Springer, Karl J. and Stahman, Ralph C., "An Investigation of Diesel Powered Vehicle Odor and Smoke," National Petroleum Refiners Association, FL 66-46 presented at the Fuels and Lubricants Meeting, Philadelphia, Pennsylvania, September 1966.

3. Springer, Karl J., "An Investigation of Diesel-Powered Vehicle Odor and Smoke, Part II," Final Report, No. AR-644, Contract PH-86-67-72, February 1968.

4. Stahman, Ralph C., Kittredge, George, and Springer, Karl J., "Smoke and Odor Control for Diesel-Powered Trucks and Buses," SAE Paper No. 680443, Mid-Year Meeting, Detroit, Michigan, May 20-24, 1968. Also SAE Transactions.

5. Springer, Karl J., "An Investigation of Diesel-Powered Vehicle Odor and Smoke - Part III," Final Report to the U. S. Public Health Service, Contract PH 22-68-23, October 1969.

6. Springer, Karl J. and Harry E. Dietzmann, "An Investigation of Diesel-Powered Vehicle Odor and Smoke - Part IV," Final Report to the Environmental Protection Agency, Contract PH 22-68-23, April 1971.

7. Springer, Karl J. and Charles T. Hare, "Four Years of Diesel Odor and Smoke Control Technology Evaluations - A Summary," ASME Paper No. 69-WA/APC-3, November 1969.

8. Dietzmann, Harry E., Springer, Karl J., and Stahman, Ralph C., "Diesel Emissions as Predictors of Observed Diesel Odor," SAE Paper No. 720757, September 1972. Also SAE Transactions.

9. Springer, Karl J. and Dietzmann, Harry E., "Diesel Exhaust Hydrocarbon Measurement - A Flame Ionization Method,"SAE Paper No. 700106, January 1970.

10. Springer, Karl J., "An Investigation of Diesel-Powered Vehicle Emissions - Part V," Final Report AR-936 to Environmental Protection Agency, Contract PH 22-68-23, April 1974.

11. Springer, Karl J., and Stahman, Ralph C., "Control of Diesel Exhaust Odors", Paper 26 presented at New York Academy of Sciences Conference on Odors: Evaluation, Utilization and Control, New York, October 1-3, 1973.

## LIST OF REFERENCES (Cont'd.)

12. Springer, Karl J., "Field Demonstration of General Motors Environmental Improvement Proposal (EIP) - a Retrofit Kit for GMC City Buses." Final Report to the Environmental Protection Agency under Contract No. PH-22-68-23, December 1972.

13. Springer, Karl J. and Stahman, Ralph C., "Diesel Emission Control Through Retrofits," SAE Paper 750205 presented at Automotive Engineering Congress and Exposition, Detroit, February 24-28, 1975.

14. Springer, Karl J., "Emissions From Diesel and Stratified Charge Powered Cars," Final Report to the Environmental Protection Agency under Contract No. PH 22-68-23, EPA Report No. EPA-460/3-75-001-a, December 1974.

15. Springer, Karl J. and Stahman, Ralph C., "Emissions and Economy of Four Diesel Cars," SAE Paper 750332 presented at Automotive Engineering Congress and Exposition, Detroit, February 24-28, 1975.

16. Springer, Karl J., "Emissions from a Gasoline- and Diesel-Powered Mercedes 220 Passenger Car," Report No. AR-813, Contract No. CPA 70-44, June 1971.

17. Springer, Karl J., and Ashby, H. Anthony, "The Low Emission Car for 1975 - Enter the Diesel," Paper No. 739133, Intersociety Energy Conversion Engineering Conference, August 1973.

18. Springer, Karl J. and Hare, Charles T., "A Field Survey to Determine Public Opinion of Diesel Engine Exhaust Odor," Final Report to the National Air Pollution Control Administration under Contract PH 22-68-36, February 1970.

19. Hare, Charles T., and Springer, Karl J., "Public Response to Diesel Engine Exhaust Odors," Final Report to the Environmental Protection Agency under Contract No. CPA 70-44, April 1971.

20. Hare, Charles T., Springer, Karl J., Somers, Joseph H., and Huls, Thomas A., "Public Opinion of Diesel Odor," SAE Paper No. 740214, presented at the Automotive Engineering Congress, Detroit Michigan, February 25 - March 1, 1974.

21. "Guide to Reduction of Smoke and Odor from Diesel-Powered Vehicles," Office of Air Programs Publications No. AP-81, Environmental Protection Agency, September 1971.

## LIST OF REFERENCES (Cont'd.)

22. Springer, Karl J. and Ludwig, Allen C., "Documentation of the Guide to Good Practice for Minimum Odor and Smoke from Diesel-Powered Vehicles," Final Report, Contract CPA 22-69-71, November 1969.

23. Springer, Karl J., White, John T., and Domke, Charles J., "Emissions from In-Use 1970-1971 Diesel-Powered Trucks and Buses." SAE Paper 741006 presented at Automobile Engineering Meeting, Toronto, Canada, October 21-25, 1974.

24. Kennedy, Gordon J., White, John T., Springer, Karl J., and Ingalls, Melvin N., "Exhaust Emissions from Heavy -Duty Trucks Tested on a Road Course and by Dynamometer," SAE Paper 750901 presented at the Automobile Engineering Meeting, Detroit, Michigan, October 13-17, 1975.

25. Hare, Charles T. and Springer, Karl J., "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines," Final Report Part 5 (Heavy Duty Farm, Construction, and Industrial Engines) to the Environmental Protection Agency under Contract No. EHS 70-108, EPA Report No. APTD-1494, October 1973.

26. Eisele, E., Hiereth, H. and Polz, H., "Experience with Comprex Pressure Wave Supercharger on the High-Speed Passenger Car Diesel Engine," SAE Paper 750334 presented at the Automotive Engineering Congress and Exposition, Detroit, Michigan, February 24-28, 1975.

27. Hare, Charles T., Springer, Karl J., and Bradow, Ronald L., "Fuel and Attitive Effects on Diesel Particulate Emissions - Development and Demonstration of Methodology, "SAE Paper 760130 presented at the 1976 Automotive Engineering Congress and Exposition, February 23-27, 1976, Detroit, Michigan.

28. Bascom, R. C. and Hass, G. C., "A Status Report on the Development of the 1973 California Diesel Emissions Standards," SAE Paper No. 700671, National West Coast Meeting, Los Angeles, August 24-27, 1970.

29. Bureau of Mines Petroleum Products Survey No. 82 titled "Diesel Fuel Oils, 1973" and dated November 1973.

30. *Federal Register*, Volume 33, No. 108, June 4, 1968

## LIST OF REFERENCES (Cont'd)

31. *Federal Register*, Volume 36, No. 40, February 27, 1971.

32. *Federal Register*, Volume 38, Number 151, Part III, August 7, 1973.

33. Turk, Amos, "Selection and Training of Judges for Sensory Evaluation of the Intensity and Character of Diesel Exhaust Odors," U. S. Department of Health, Education and Welfare, Public Health Service, 1967.

34. Black, F. M., High, L. E., and Sigsby, J. E., "Methodology for Assignment of a Hydrocarbon Photochemical Reactivity Index for Emissions from Mobile Sources." Final Report to the Environmental Protection Agency, EPA Report No. EPA-650/2-75-025, March 1975.

35. Sawicki, E., Corey, R. C., and Dooley, A. E.,:Health Lab Sci. (Suppl. 1), 56-59, 1970.

36. Chemical Identification of the Odor Components in Diesel Engine Exhuast, Final Report, July 1969, CRC Project CAPE-7-68, HEW Contract PH 22-68-20.

37. Chemical Identification of the Odor Components in Diesel Engine Exhaust, Final Report, Jun 1970, CRC Project CAPE-7-68 HEW Contract No. CPA 22-69-63.

38. Chemical Identification of the Odor Components in Diesel Engine Exhaust, Final Report, June 1971, CRC Project CAPE 7-68, EPA Contract No. EHSD 71-18.

39. Analysis of the Odorous Compounds in Diesel Engine Exhaust Final Report, June 1972, CRC Project CAPE 7-68, EPA Contract No. 68-02-0087.

40. Levins, P. L. and Kendall, D. A., "Application of Odor Technology to Mobile Source Emission Instrumentation," CRC Project CAPE-7-68, Contract No. 68-02-0561, September 1973.

41. Gross, George P., "The Effect of Fuel and Vehicle Variables on Polynuclear Aromatic Hydrocarbon and Phenol Emissions," SAE Paper 720210 presented at the Automotive Engineering Congress, January 1972.

42. Gross, George P., "Automotive Emissions of Polynuclear Aromatic Hydrocarbons," SAE Paper 740564, September 1973.

# APPENDIX A

## SELECTED TABLES AND FIGURES FROM PETROLEUM PRODUCTS SURVEY NO. 82

"DIESEL FUEL OILS, 1973"

BUREAU OF MINES
U. S. DEPARTMENT OF THE INTERIOR

NOVEMBER 1973

TABLE 1.--Summary of Type C-B fuels

Diesel fuel survey, 1973

| Geographic distribution of diesel fuels<br>Districts within region<br>Additional districts<br>Number of fuels | | Eastern region<br>A,B,C<br>D,E,F,G<br>38 | | | Southern region<br>D<br>A,B,C,E,F,G,I,J<br>15 | | | Central region<br>E,F,G<br>A,B,C,D,H,I,J,K,L<br>34 | | | Rocky Mountain region<br>H,I,J,K<br>D,E,F,G,L,M,N,O,P<br>13 | | | Western region<br>L,M,N,O,P<br>F,H,I,J,K<br>14 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test | ASTM | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum |
| Gravity, °API | D287 | 32.3 | 41.4 | 47.9 | 35.4 | 41.0 | 42.7 | 32.3 | 40.9 | 44.7 | 35.0 | 40.9 | 43.8 | 33.4 | 42.7 | 47.6 |
| Flash point, °F | D93 | 122 | - | 194 | 126 | - | 176 | 122 | - | 194 | 122 | - | 176 | 122 | - | 178 |
| Color: | | | | | | | | | | | | | | | | |
| ASTM | D1500 | L0.5 | - | L1.0 | - | - | - | L0.5 | - | 1.0 | L0.5 | - | L1.0 | L0.5 | - | L1.0 |
| Saybolt chromometer | D156 | +30 | - | +11 | +30 | - | +21 | +30 | - | +17 | +30 | - | +20 | +30 | - | +18 |
| Viscosity at 100° F: | | | | | | | | | | | | | | | | |
| Kinematic, cs | D445 | 1.50 | 1.90 | 3.42 | 1.50 | 1.85 | 2.92 | 1.45 | 1.93 | 3.05 | 1.50 | 1.93 | 3.05 | 1.44 | 1.77 | 3.01 |
| Saybolt Universal, sec. | D88 | - | 32.3 | 37.3 | - | 32.1 | 35.7 | - | 32.4 | 36.1 | - | 32.4 | 36.1 | - | - | 36.0 |
| Cloud point, °F | D2500 | <-66 | - | 20 | -60 | - | 6 | -56 | - | 10 | -62 | - | 10 | -62 | - | 14 |
| Pour point, °F | D97 | <-65 | - | 0 | <-65 | - | -5 | -60 | - | -5 | -65 | - | -5 | -65 | - | 5 |
| Sulfur content, wt% | D129 | 0.011 | 0.100 | 0.34 | 0.01 | 0.050 | 0.222 | 0.015 | 0.130 | 0.464 | 0.001 | 0.112 | 0.464 | 0.001 | 0.089 | 0.38 |
| Aniline point, °F | D611 | 130.5 | 149.1 | 178.0 | 138.0 | 146.9 | 160.6 | 130.5 | 146.8 | 160.6 | 138.0 | 148.3 | 160.6 | 139.9 | 147.9 | 161.9 |
| Carbon residue on 10%, wt% | D524 | 0.00 | 0.076 | 0.19 | 0.005 | 0.073 | 0.19 | 0.03 | 0.081 | 0.19 | 0.00 | 0.058 | 0.090 | 0.01 | 0.055 | 0.120 |
| Ash, wt% | D482 | 0.000 | 0.001 | 0.007 | 0.000 | < 0.001 | 0.002 | 0.000 | 0.001 | 0.007 | 0.000 | 0.001 | 0.002 | 0.000 | 0.001 | 0.005 |
| Cetane number | D613 | 43.0 | 49.8 | 65.3 | 43.0 | 47.1 | 54.6 | 42.3 | 49.1 | 54.6 | 39.0 | 48.6 | 54.6 | 39.0 | 50.8 | 65.3 |
| Distillation temp, °F, volume recovered: | D86 | | | | | | | | | | | | | | | |
| IBP | | 318 | 352 | 412 | 324 | 347 | 387 | 324 | 353 | 412 | 320 | 352 | 398 | 320 | 350 | 408 |
| 10% | | 350 | 394 | 460 | 364 | 388 | 442 | 350 | 393 | 460 | 360 | 393 | 442 | 360 | 387 | 454 |
| 50% | | 407 | 445 | 530 | 411 | 437 | 514 | 408 | 446 | 514 | 404 | 449 | 514 | 404 | 438 | 525 |
| 90% | | 444 | 506 | 604 | 465 | 497 | 590 | 465 | 510 | 590 | 472 | 516 | 590 | 456 | 498 | 574 |
| End point | | 490 | 545 | 645 | 499 | 533 | 637 | 498 | 549 | 637 | 496 | 556 | 634 | 496 | 537 | 608 |

Diesel fuel survey, 1972

| Geographic distribution of diesel fuels<br>Districts within region<br>Additional districts<br>Number of fuels | | Eastern region<br>A,B,C<br>D,E,F,G<br>35 | | | Southern region<br>D<br>A,B,C,E,F,G,I,J<br>16 | | | Central region<br>E,F,G<br>A,B,C,D,H,I,J,K<br>L,M,N,O,P<br>32 | | | Rocky Mountain region<br>H,I,J,K<br>D,E,F,G,H,I,J,K<br>L,M,N,O,P<br>13 | | | Western region<br>L,M,N,O,P<br>F,G,H,I,J,K<br>18 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test | ASTM | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum |
| Gravity, °API | D287 | 34.1 | 41.8 | 45.0 | 31.9 | 40.0 | 43.6 | 33.8 | 41.0 | 44.4 | 35.4 | 41.2 | 44.4 | 36.4 | 41.2 | 44.9 |
| Flash point, °F | D93 | 120 | - | 206 | 128 | - | 172 | 124 | - | 206 | 124 | - | 174 | 128 | - | 180 |
| Color: | | | | | | | | | | | | | | | | |
| ASTM | D1500 | L0.5 | - | 0.5 | L0.5 | - | 1.0 | L0.5 | - | 1.0 | L0.5 | - | 1.0 | L0.5 | - | 2.5 |
| Saybolt chromometer | D156 | +30 | - | +19 | +30 | - | +18 | +30 | - | +17 | +30 | - | +21 | +30 | - | +17 |
| Viscosity at 100° F: | | | | | | | | | | | | | | | | |
| Kinematic, cs | D445 | 1.45 | 1.92 | 3.41 | 1.45 | 2.11 | 3.37 | 1.50 | 1.90 | 2.98 | 1.46 | 1.89 | 2.98 | 1.40 | 2.06 | 3.50 |
| Saybolt Universal, sec. | D88 | - | 32.3 | 37.3 | - | 33.0 | 37.2 | - | 32.3 | 35.9 | - | 32.2 | 35.9 | - | 33.1 | 37.6 |
| Cloud point, °F | D2500 | -60 | - | 14 | -60 | - | 4 | -60 | - | 4 | -70 | - | 4 | -70 | - | 16 |
| Pour point, °F | D97 | -60 | - | 0 | -60 | - | -5 | -60 | - | -5 | -60 | - | -5 | -65 | - | 10 |
| Sulfur content, wt% | D129 | 0.0004 | 0.083 | 0.32 | 0.009 | 0.068 | 0.23 | 0.01 | 0.133 | 0.46 | 0.004 | 0.113 | 0.46 | 0.004 | 0.075 | 0.36 |
| Aniline point, °F | D611 | 134.2 | 150.5 | 180.0 | 131.5 | 146.0 | 155.5 | 134.2 | 146.2 | 155.0 | 135.2 | 146.9 | 154.0 | 134.0 | 148.6 | 158.9 |
| Carbon residue on 10%, wt% | D524 | 0.00 | 0.065 | 0.20 | 0.00 | 0.072 | 0.13 | 0.00 | 0.075 | 0.29 | 0.04 | 0.089 | 0.11 | 0.01 | 0.072 | 0.15 |
| Ash, wt% | D482 | 0.000 | 0.001 | 0.005 | 0.000 | 0.000 | 0.002 | 0.000 | 0.001 | 0.005 | 0.000 | <0.001 | 0.002 | 0.000 | 0.001 | 0.001 |
| Cetane number | D613 | 44.0 | 51.0 | 65.0 | 40.0 | 48.1 | 59.4 | 43.3 | 49.8 | 59.4 | 42.0 | 49.4 | 59.4 | 40.8 | 49.8 | 56.6 |
| Distillation temp, °F, volume recovered: | D86 | | | | | | | | | | | | | | | |
| IBP | | 319 | 356 | 408 | 336 | 354 | 400 | 316 | 352 | 408 | 311 | 355 | 404 | 311 | 345 | 382 |
| 10% | | 360 | 394 | 460 | 366 | 403 | 458 | 362 | 393 | 458 | 345 | 395 | 458 | 345 | 393 | 457 |
| 50% | | 408 | 445 | 530 | 405 | 458 | 543 | 403 | 446 | 543 | 394 | 446 | 543 | 394 | 453 | 535 |
| 90% | | 444 | 508 | 608 | 461 | 518 | 606 | 462 | 510 | 593 | 459 | 508 | 593 | 459 | 512 | 609 |
| End point | | 490 | 566 | 648 | 496 | 555 | 642 | 498 | 551 | 652 | 491 | 548 | 652 | 491 | 553 | 655 |

TABLE 2.--Summary of Type T-T fuels

Diesel fuel survey, 1973

| Geographic distribution of diesel fuels<br>Districts within region<br>Additional districts<br>Number of fuels | | Eastern region<br>A,B,C<br>D,E,F,G<br>57 | | | Southern region<br>D<br>A,B,C,E,F,G,I,J<br>30 | | | Central region<br>E,F,G<br>A,B,C,D,H,I,J,K,L<br>75 | | | Rocky Mountain region<br>H,I,J,K<br>D,E,F,G,L,M,N,O<br>38 | | | Western region<br>L,M,N,O,P<br>F,H,I,J,K<br>32 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test | ASTM | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum |
| Gravity, °API | D287 | 31.5 | 36.1 | 44.7 | 31.5 | 35.8 | 42.5 | 30.0 | 36.6 | 44.7 | 30.0 | 36.6 | 44.3 | 30.0 | 36.7 | 44.7 |
| Flash point, °F | D93 | 122 | - | 194 | 128 | - | 190 | 122 | - | 226 | 136 | - | 206 | 110 | - | 216 |
| Color, ASTM | D1500 | L0.5 | - | 1.5 | L0.5 | - | 1.5 | L0.5 | - | 2.0 | L0.5 | - | L2.0 | L0.5 | - | 2.5 |
| Viscosity at 100° F: | | | | | | | | | | | | | | | | |
| Kinematic, cs | D445 | 1.50 | 2.56 | 3.54 | 1.50 | 2.73 | 3.77 | 1.50 | 2.61 | 3.77 | 1.66 | 2.67 | 3.90 | 1.27 | 2.79 | 8.25 |
| Saybolt Universal, sec. | D88 | - | 34.5 | 37.7 | - | 35.1 | 38.4 | - | 34.7 | 38.4 | - | 34.9 | 38.9 | - | 35.3 | 40.0 |
| Cloud point, °F | D2500 | -42 | - | 24 | <-26 | - | 12 | <-50 | - | 16 | -40 | - | 30 | <-70 | - | 38 |
| Pour point, °F | D97 | -60 | - | 15 | -60 | - | 5 | -50 | - | 10 | -50 | - | 25 | <-70 | - | 30 |
| Sulfur content, wt% | D129 | 0.02 | 0.192 | 0.50 | 0.02 | 0.235 | 1.1 | 0.002 | 0.236 | 0.76 | 0.02 | 0.251 | 0.648 | 0.003 | 0.230 | 0.49 |
| Aniline point, °F | D611 | 122.5 | 142.7 | 178.0 | 126.0 | 145.1 | 160.6 | 122.5 | 145.7 | 172.0 | 130.0 | 148.3 | 160.6 | 127.5 | 146.5 | 160.0 |
| Carbon residue on 10%, wt% | D524 | 0.00 | 0.109 | 0.33 | 0.01 | 0.102 | 0.237 | 0.015 | 0.110 | 0.33 | 0.00 | 0.091 | 0.237 | 0.04 | 0.097 | 0.15 |
| Ash, wt% | D482 | 0.000 | 0.002 | 0.06 | 0.000 | <0.001 | 0.004 | 0.000 | 0.001 | 0.009 | 0.000 | 0.001 | 0.006 | 0.000 | 0.002 | 0.006 |
| Cetane number | D613 | 39.0 | 46.9 | 63.1 | 40.1 | 47.0 | 56.0 | 39.0 | 48.6 | 56.0 | 40.6 | 48.7 | 54.8 | 41.0 | 48.7 | 63.7 |
| Distillation temp, °F, volume recovered: | D86 | | | | | | | | | | | | | | | |
| IBP | | 309 | 366 | 412 | 324 | 368 | 412 | 326 | 377 | 463 | 341 | 378 | 436 | 319 | 375 | 450 |
| 10% | | 364 | 423 | 466 | 364 | 425 | 466 | 366 | 425 | 483 | 376 | 429 | 489 | 346 | 430 | 489 |
| 50% | | 408 | 493 | 533 | 417 | 497 | 534 | 408 | 493 | 535 | 428 | 493 | 544 | 389 | 498 | 545 |
| 90% | | 465 | 572 | 628 | 467 | 579 | 648 | 465 | 571 | 648 | 484 | 574 | 656 | 455 | 580 | 626 |
| End point | | 507 | 618 | 698 | 507 | 624 | 692 | 500 | 613 | 692 | 509 | 619 | 700 | 489 | 624 | 670 |

Diesel fuel survey, 1972

| Geographic distribution of diesel fuels<br>Districts within region<br>Additional districts<br>Number of fuels | | Eastern region<br>A,B,C<br>D,E,F,G<br>62 | | | Southern region<br>D<br>A,B,C,E,F,G,I,J<br>L,M,N,O<br>37 | | | Central region<br>E,F,G<br>A,B,C,D,H,I,J,K<br>L,M,N,O<br>47 | | | Rocky Mountain region<br>H,I,J,K<br>D,E,F,G,L,M,N,O<br>35 | | | Western region<br>L,M,N,O,P<br>D,E,F,G,H,I,J,K<br>31 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test | ASTM | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum |
| Gravity, °API | D287 | 31.8 | 36.8 | 47.5 | 31.8 | 35.7 | 41.7 | 32.8 | 36.8 | 44.1 | 33.0 | 36.8 | 43.4 | 31.2 | 36.4 | 44.5 |
| Flash point, °F | D93 | 120 | - | 206 | 138 | - | 220 | 128 | - | 224 | 140 | - | 220 | 130 | - | 238 |
| Color, ASTM | D1500 | L0.5 | - | 2.0 | L0.5 | - | L1.5 | L0.5 | - | L2.0 | L0.5 | - | L2.0 | L0.5 | - | 3.5 |
| Viscosity at 100° F: | | | | | | | | | | | | | | | | |
| Kinematic, cs | D445 | 1.48 | 2.60 | 3.80 | 1.58 | 2.78 | 3.99 | 1.50 | 2.58 | 3.81 | 1.68 | 2.66 | 3.99 | 1.31 | 2.94 | 4.25 |
| Saybolt Universal, sec. | D88 | - | 34.6 | 38.6 | - | 35.2 | 39.2 | - | 34.6 | 38.1 | - | 34.8 | 39.2 | - | 35.8 | 40.0 |
| Cloud point, °F | D2500 | -52 | - | 20 | -42 | - | 18 | -50 | - | 20 | -38 | - | 32 | -62 | - | 36 |
| Pour point, °F | D97 | -50 | - | 10 | -40 | - | 5 | -55 | - | 10 | -50 | - | 25 | -65 | - | 30 |
| Sulfur content, wt% | D129 | 0.005 | 0.168 | 0.520 | 0.018 | 0.194 | 1.1 | 0.007 | 0.229 | 0.70 | 0.009 | 0.243 | 0.50 | 0.005 | 0.218 | 0.43 |
| Aniline point, °F | D611 | 111.0 | 145.4 | 180.0 | 125.0 | 145.4 | 160.0 | 111.0 | 145.9 | 171.0 | 131.7 | 147.5 | 169.5 | 134.0 | 149.2 | 160.5 |
| Carbon residue on 10%, wt% | D524 | 0.00 | 0.092 | 0.20 | 0.00 | 0.104 | 0.23 | 0.00 | 0.106 | 0.23 | 0.00 | 0.093 | 0.23 | 0.01 | 0.092 | 0.20 |
| Ash, wt% | D482 | 0.000 | 0.001 | 0.006 | 0.000 | <0.001 | 0.004 | 0.000 | 0.001 | 0.006 | 0.000 | 0.001 | 0.01 | 0.000 | 0.001 | 0.01 |
| Cetane number | D613 | 40.1 | 49.0 | 65.0 | 40.0 | 47.1 | 59.4 | 40.1 | 49.0 | 59.4 | 42.9 | 49.0 | 59.4 | 40.8 | 49.1 | 62.5 |
| Distillation temp, °F, volume recovered: | D86 | | | | | | | | | | | | | | | |
| IBP | | 270 | 370 | 412 | 320 | 372 | 430 | 325 | 375 | 453 | 324 | 380 | 430 | 315 | 378 | 490 |
| 10% | | 364 | 424 | 471 | 386 | 430 | 489 | 364 | 425 | 492 | 387 | 431 | 489 | 352 | 438 | 522 |
| 50% | | 408 | 492 | 544 | 422 | 502 | 548 | 412 | 493 | 550 | 424 | 495 | 548 | 393 | 507 | 549 |
| 90% | | 444 | 569 | 608 | 463 | 578 | 646 | 461 | 570 | 646 | 472 | 575 | 637 | 453 | 582 | 637 |
| End point | | 494 | 613 | 654 | 502 | 623 | 696 | 508 | 612 | 696 | 498 | 618 | 687 | 504 | 626 | 687 |

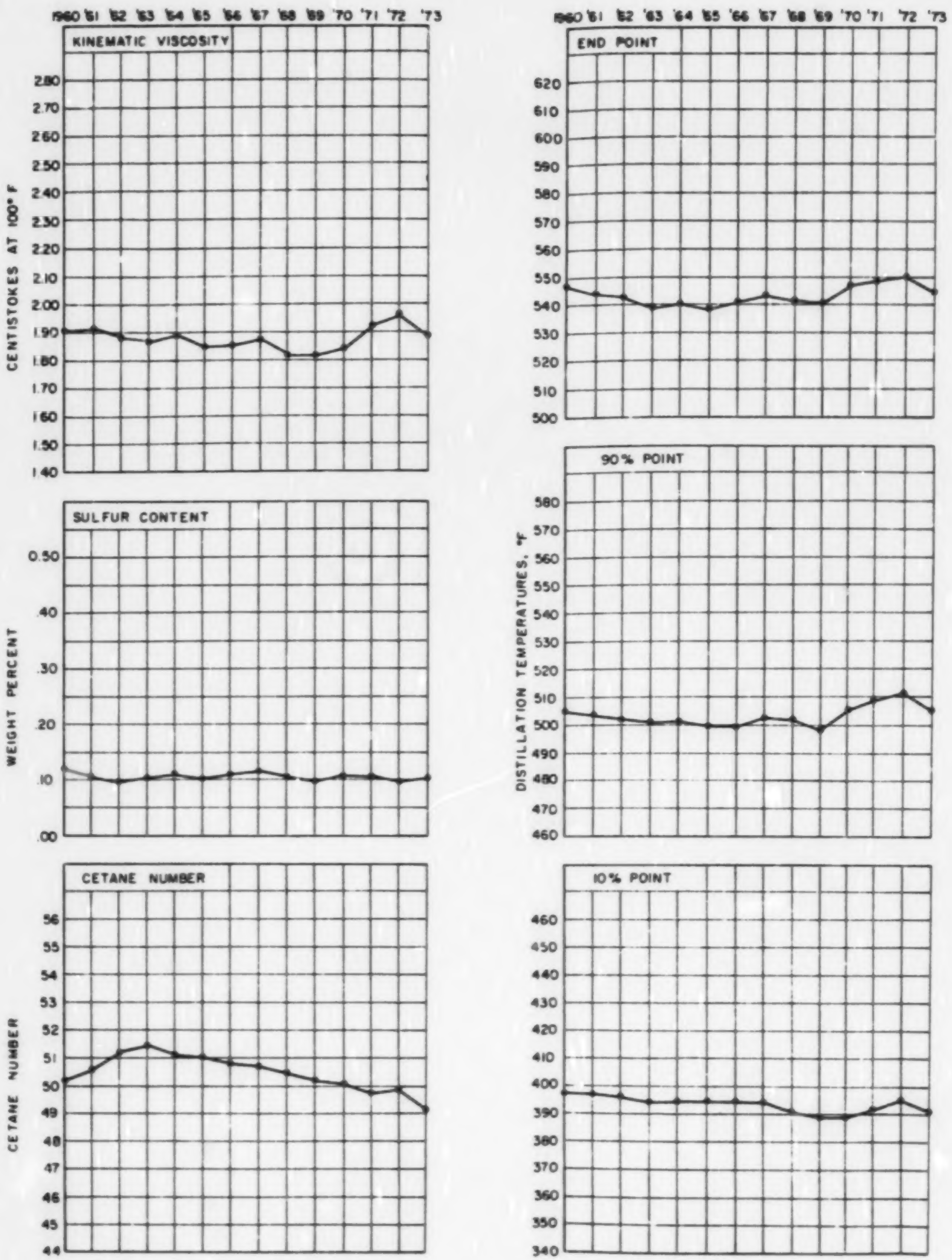


FIGURE 2.-Trends of Some Properties of Type C-B Diesel Fuel Oils.

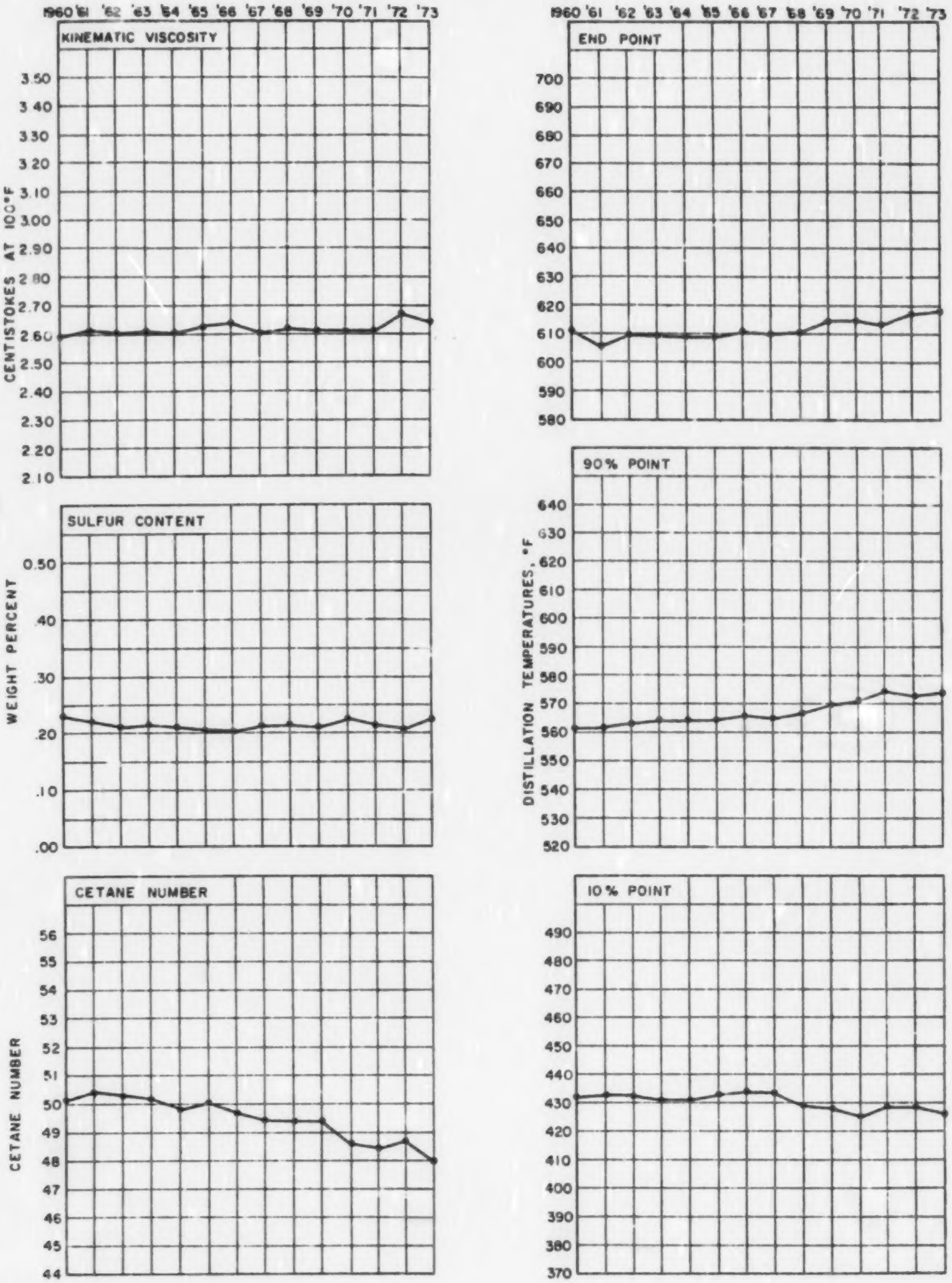


FIGURE 3.-Trends of Some Properties of Type T-T Diesel Fuel Oils.

# APPENDIX B

## CHEMICAL - ANALYTICAL PROCEDURES

# OXYGENATED COMPOUNDS IN AUTOMOBILE EXHAUST-GAS CHROMATOGRAPHIC PROCEDURE

Fred Stump

## 1. Principles and Applicability

1.1 This method is applicable for the characterization of oxygenated compounds in automobile exhaust.

Aldehydes have been shown (1) to be about as photochemically reactive as olefins. The aldehydes are believed to be contributors to eye irritation as well as odors that are common in polluted atmospheres.

Analysis of exhaust samples from catalytic and non-catalytic cars show that formaldehyde, acetaldehyde, acetone/acrolein/propionaldehyde, crotonaldehyde and benzaldehyde are consistently present in vehicle emissions withiso-butyraldehyde and hexanaldehyde being intermittently observed. With the present analytical equipment setup acetone, acrolein, and propionaldehyde have the same chromatographic relative retention time. Since the components in this time zone are not resolved, all effluents occuring at this retention time are calculated as acetone.

1.2 The vehicular exhaust is first diluted in a constant volume sampler system and then a portion of this dilute exhaust is pulled through a manifold sampling system. The sample is taken through two impingers in series each of which contains 40 ml of absorbing reagent. The absorbing reagent is a solution of 2,4-Dinitrophenylhydrazine in 2N HCl. The carbonyl compounds present in the sample stream react with the absorbing reagent forming soluble and insoluble derivatives which are removed by filtration and extraction techniques. These separated derivatives are then dried, and the soluble and precipitated portions are recombined prior to analysis. A single gas chromatographic analysis is then made to characterize the combined sample.

## 2. Range and Sensitivity

The mechanics of the method (sampling volumes, extraction techniques, and analytical procedure) were designed around the established dilution (CVS) system and then set-up manifold sampler. The analytical procedure has been shown to have a total recovery of better than 95% when the effluent concentrations are in the range of 0.01 to 30 parts per million.

The limits of detectability as well as the range can be easily adjusted to satisfy all measurement conditions that have been encountered up to the present time.

## 3. Interferences

No significant interferences in the method have been detected.

## 4. Precision, Accuracy and Stability

### 4.1 Precision

Data obtained from 5 repetitive injections of standard derivatives in benzene has shown the maximum deviation to be 0.8% for benzaldehyde and a minimum deviation of 0.3% for formaldehyde.

### 4.2 Accuracy

The data obtained from a standard mix of derivatives in absorbing reagent solution (to simulate actual sample recovery conditions) indicate a recovery in excess of 97%.

### 4.3 Stability

Data from standard mixes indicate that no significant concentration changes occurred when the solution was left standing for a period of 5 days.

## 5. Apparatus

### 5.1 Hardware

A. Perkin-Elmer 900 Gas Chromatograph with dual columns and flame ionization detectors with a single differential amplifier.

B. Perkin-Elmer PEP-1 Data Systems for peak area retention time and area integration.

C. Electronik 19 Model Honeywell recorder for chromatographic display.

D. Dual column 24 x 1/8 inch O.D. (0.093) stainless steel tubing packed with 6.7% Dexsil (polycarboranesiloxane) 300 GC on Chromosorb G 60/80 mesh, DMCS treated and acid washed.

E. 100 ml capacity impinger type scrubbers. Ace Glass # 7530-07.

F. 125 ml capacity vacuum and volatile liquid flasks.

G. Calibrated rotometers capable of measuring at least 3 liters per minute.

H. Three fritted glass filters porosity "D", ASTM 10-20 microns pore size. Ace Glass Company

I. Separatory funnels 125 and 250 ml capacity.

J. Separatory funnel shaker, Wrist-Action ® type with appropriate funnel holders.

K. Nitrogen manifold or explosion proof constant temperature vacuum oven.

L. Volumetric dispensing flasks, wash bottles, graduated cylinders, and 1 dram vials.

M. Ring stands, labels, holders, tubing, fittings and clamps needed for equipment manipulation.

N. Pump, Gast Model 0211-P103A-G8C.

O. Heated manifold, See Figure 2.

6. Reagents

6.1 Pentane, Spectroquality

6.2 2,4-Dinitrophenyhydrazine (2,4-DNPH).

6.2.1 A 2N HCl solution of reagent grade 2,4-DNPH, saturated at 0°C is prepared as follows:

A. To a 1-liter volumetric flask containing about 500 ml of distilled water, add 163 ml of concentrated HCl and 2.5 grams of the 2,4-DNPH crystals.

B. Dissolve crystals using either an ultrasonic generator bath or an automatic stirrer with a teflon coated stirring bar.

C. If reagent is not to be used immediately, store the stoppered flask in a refrigerator as near to 0°C as possible. The storage period should not exceed 10 days. Discard solution if crystals begin to form before this ten day period expires.

6.2.2 Due to contamination present in both the pentane and 2,4-DNPH reagents it is more expedient to obtain a background by performing at least duplicate extractions on the absorbing reagent in the same manner as samples are treated. Since the contaminants vary in concentration from lot to lot it will be necessary to obtain a background when new lots or batches of reagents are introduced. These background values have been found to be extremely vital in correcting sample concentrations.

### 6.3 Sodium Bicarbonate

## 7. Procedure

### 7.1 Calibration

7.1.1 Anthracene functions as the internal standard and is presently prepared at a concentration of 0.041580 mg/ml. The anthracene is dissolved in spectroquality Benzene and two ml of this prepared solution is used to dissolve the dried oxygenate derivatives prior to analysis.

7.1.2 Response factors for the individual carbonyls are determined from standard concentrations of pure 2,4-DNPH derivatives in spectroquality Benzene. The purity of the synthesized derivatives must be checked by a melting point (2) determination before derivatives are used to obtain the response factors. Typical response factors and concentration repeatability for the hydrazone derivatives normally found in exhaust are shown in Table I. The response factors for each carbonyl is calculated from the following equation:

$$\text{Response Factor (F)} = \frac{\text{Anthracene Area}}{\text{Derivative Area}} \times \frac{\text{mg/ml Derivative}}{\text{mg/ml Anthracene}}$$

### 7.2 Oxygenate collection and recovery

#### 7.2.1 Sample Collection

A. Pipette 40 ml of reagent solution into 6 impingers.

B. The two impingers are connected in series for each bag so that the collection efficiency can be calculated.

C. Place the assembled impingers in an ice bath.

D. Collect the samples noting the flow rate, room temperature, barometric pressure and total sampling time.

E. The sample is taken through a heated manifold system connected into the dilution system and collected under the conditions described in the Federal Register, Volume 37, Number 221, Part II, Wednesday, November 15, 1972, New Motor Vehicles and New Motor Vehicles Engines.

F. The manifold collection system is electrically slaved to the CVS dilution system so that the impinger sampling time corresponds to Federal Cycle run times.

G. Disconnect the impingers from the manifold. Partially remove the impinger tube assembly until the stem is above the liquid and wash any precipitates and reagent from both the internal and external surfaces of the stem with a few milliters of distilled water. Allow the excess water to drain from the stem and remove the impinger tube from the absorber bottle. Let sample set at room temperature at least one hour before proceeding to the filtration and extraction steps.

7.2.2 Samples containing precipitates

A. Attach the side arm of a 125 ml vacuum flask containing a fritted glass filter to a vacuum line and apply vacuum.

B. Transfer the contents of the absorber to the fritted glass filter assembly and rinse absorber with small portions of distilled water.

C. Wash the precipitate on the fritted filter with a few ml of distilled water.

D. Shut off vacuum and transfer contents of vacuum flask to a 125 ml separatory funnel. Rinse vacuum flask with small volumes of distilled water until rinse is essentially colorless.

E. Remove filter with precipitates and put a second filter on the flask and apply vacuum. Repeat steps B through D for each succeeding sample.

F. Dry filters under a steam of nitrogen or in a vacuum oven at 50°C and 18" water vacuum. Set the filters with the dried precipitate until the filtrate has been processed then proceed to step G.

G. When precipitate is dry place the filter on a dry 125 ml vacuum flask.

H. Pour 15 ml of methylene chloride over the precipitate and let set for approximately 30 seconds until the precipitate has dissolved. Apply vacuum and pull the solution through the filter. Add a second 15 ml of methylene chloride to the filter and gently swirl around to wash the filter funnel as well as to dissolve any residual materials. Apply vacuum to pull this second volume of methylene chloride into the vacuum flask.

I. Transfer the dissolved hydrazines with a 15 ml washing of methylene chloride to the 125 ml gas tight flask, containing the dried extract corresponding to this precipitate.

J. Repeat steps A through I for each sample containing a precipitate.

### 7.2.3 Samples With No or Removed Precipitates

A. Transfer contents of absorber or vacuum flask to a 125 ml separatory funnel washing the absorber bottle or flask with small volumes of distilled water.

B. To the separatory funnel containing the absorbing reagent, add 40 ml of pentane (the background of which has been determined). Stopper the funnel and then put it into the automatic shaker holder. Vent the funnel. Start the shaker and let it shake for 5 minutes.

C. Stop shaker and vent funnel. Allow the two-phase system to separate, collecting the lower phase in a second separatory funnel. Transfer the remaining pentane extract portion to a 250 ml separatory funnel. Add a second 40 ml of pentane to the already once extracted sample solution. Repeat steps B and C.

D. Repeat steps B and C a third time.

E. To the 250 ml separatory funnel containing the 120 ml of pentane extract drain off the absorbing reagent which had been transferred with the pentane.

F. Add 25 ml of distilled water to the funnel, then approximately 1/4 to 1/2 grams of sodium bicarbonate. Wash lip of funnel free of material, put stopper in funnel and then manually shake for 30 seconds.

G. Let phases separate and drain the wash water from the funnel, and again add 25 ml of distilled water and repeat the shaking. After the phases have separated, drain off the water, insuring that all traces are removed, as the presence of water will now extend the time required to evaporate the extract to dryness.

H. Wipe lip of funnel with a dry paper towel and transfer the contents to a clean, dry 125 ml air tight flask. The flasks can either be placed in a vacuum oven at 50°C and 18 inches of water vacuum or under a steam of dry nitrogen until the pentane has been removed and only the dried derivatives remain.

I. Repeat steps A through H for each sample.

J. When the samples have come to dryness, remove from oven or nitrogen steam and set aside until the precipitates have been processed.

K. After the precipitates have been dried and dissolved in methylene chloride add this solution to the flasks containing the dried extracted portion of the sample. This solution is then taken to dryness under the conditions in step H above.

L. Pipette into each of the 125 ml gas tight flasks containing the dried 2, 4-DNPH derivatives (extract and precipitate) 2 ml of the Internal Standard (Anthracene in Benzene) Solution and place the flask in a sonic bath until the residue has dissolved. Visually examine the bottom of the flasks, by holding up to a light area, to insure that all of the residue has completely dissolved.

M. Transfer the solution from step L to a labeled 1 dram vial in preparation for gas chromatographic injection.

### 7.3 Analysis

#### 7.3.1 Optimization of Parameters

A. Prior to calibration and determination of response factors the hydrogen, helium (carrier), and air flows must be optimized using a standard mix in benzene. This flow-response calibration procedure can be found in most gas chromatographic books.

B. The conditions presently in use were obtained by first optimizing the hydrogen-air flows at low, medium, and high helium carrier rotometer settings. A number of injections were made at each of the above conditions using different sample sizes. The best chromatographic conditions, flow rates measured at detector, were found to be at a helium flow rate of 40.0 cc/min., hydrogen flow rate 45.5 cc/min., and air at a flow of 600 cc/min. with a sample size of 15 microliters.

#### 7.3.2 Technique

A. Condition the chromatograph column with a 15 microliter portion of either a standard mixture or sample prior to obtaining concentration data. A conditioning process should be repeated whenever samples are not analyzed for an hour or more.

B. The injection is on-column using a 25 microliter syringe. Before injection, at least 3-25 microliter portions of the sample is used to condition the syringe. A 25 microliter portion is then taken into the syringe and syringe laid on a clean paper towel. The chromatograph lid is raised and a wrench is used to remove the column tee cap. The tee is a 3-way fitting shaped the capital "T" and is situated such that the vertical section of the "T" is on the horizontal plane. A cap is placed on one side of the "T" top and the column of the other side. The carrier gas enters the side arm and exits through the column side of the "T". The syringe is then taken up and the volume adjusted from 25 to 15 microliters. The syringe tip is wiped free of any liquid and then inserted through the "T" into the column and the plunger firmly pushed in. The syringe is removed and a cold cap put on the tee, tightened, and then the lid closed. When the chromatograph responds to the benzene solvent the GC programmed start button is pressed simultaneously with the inject data systems interface initiator. The syringe is then washed several times with clean benzene in preparation for the next injection.

C. The GC temperature is programmed from 130°C to 300°C at a rate of 6°C per minute. Injection block temperature is 240°C and the manifold temperature held at 300°C.

D. See Figure I for a typical exhaust chromatogram of a non-catalytic automobile.

## 8. Calibrations

### 8.1 Absorber Inefficiency-Series Impingers

### 8.1.1 Using a Programmable Calculator

Corrections for absorber inefficiency for an infinite number of absorbers is based on the material balance concept. This method for determining the total concentration of carbonyl compounds using two absorbers in series has been verified within experimental error using a multiple impinger train.

These calculations are essential for an accurate determination of, particularly, the acetaldehyde and acetone concentrations. The percent of acetaldehyde passing through the first absorber is about 7.5% of the material present in the absorber and for acetone/acrolein/propionaldehyde is in the order of 20% of the material in the first absorber.

Calculations for series impingers are made by using the following equations:

First using the formula

$$R_n = A_0 + A_1 \sum R_i$$

when $R_n$ = Concentration in each absorber

N-1

$\sum R_i$ = sum of individual absorber concentrations

The concentrations present in the series absorbers are used to determine the constants $A_0$ and $A_1$.

The constants $A_0$ and $A_1$ are then used to calculate the total uncorrected concentration by equation.

$$C_0 = \frac{A_0}{K} = \frac{A_0}{A_1 V_s} \quad \text{where:}$$

$A_0$ = material removed from sample stream by first absorbers.

$A_1$ = material removed by second and succeeding absorbers.

$V_s$ = sample volume

K = Constant

The value of $C_0$ is then corrected by a background subtraction.

For example:

Since the material balance concept dictates that the quantity of material absorbed by each of the absorbers in a train is related, then the linear regression equation can be used to determine the values of the slope and intercept of any two absorbers in series. Know these two constants for any two absorbers the total concentration can then be calculated for the sample steam.

Example:

| Absorber in train | Concentration in Absorber |
|---|---|
| 1st | .1600 |
| 2nd | .0800 |
| 3rd | .0400 |
| 4th | .0200 |

Data Points:

| $R_n$ (y) | $\sum^{N-1} R_i$ ( x ) |
|---|---|
| .1600 | 0 |
| .0800 | .1600 |
| .0400 | .2400 |
| .0200 | .2800 |

When calculated for an infinite number of absorbers.

$$C_0 = \frac{A_0}{A_1} = \frac{.16}{.50} = .32$$

### 8.1.2 Alternate Method

An alternate method for doing the calculations if a programmable calculator is not available would be run two absorbers in series and then based on this information a per cent of the material passing through the first impinger could be determined. This per cent could then be applied to any number of hypothetical absorbers and then summed to give a total concentration.

After sufficient data has been obtained on series absorbers then only one absorber can be run and calculations made, with confidence, to get a total concentration.

### 8.2 Carbonyl Concentration

$$\text{Carbonyl (ppm)} = C_1 \times \frac{1}{V_s} \times \frac{T_r}{P_r} \times \frac{F}{MW} \times \frac{2\ \text{I.S.} \times 10^3}{\frac{T_o}{P_oV_o}}$$

$C_1$ = Co corrected for background
$V_s$ = Sample volume in liter
$T_r$ = Room temperature, °K
$P_r$ = Room pressure, mm Mercury
F = Response factor for individual carbonyl
MW = Molecular weight of carbonyl derivative
I.S. = Internal Standard Concentration, mg/ml
$T_o$ = Temperature at Standard Conditions
$P_o$ = Pressure at Standard Conditions
$V_o$ = Volume at Standard Conditions

## TABLE 1. STANDARD MIXTURE OF 2,4-DNPH DERIVATIVES FOR THE CALIBRATION OF THE CHROMATOGRAPHIC SYSTEM

| | | | Ratio Anthracene to 2,4-DNPH | | |
|---|---|---|---|---|---|
| 2,4-DNPH Derivative | Number of Determinations | Concentration mg/ml | $\bar{X}$ | Standard Deviation | F-Factor |
| Formaldehyde | 5 | 0.09896 | 1.0851 | 0.0032 | 2.5293 |
| Acetaldehyde | 5 | 0.10395 | 0.9181 | 0.0028 | 2.2481 |
| Acetone | 5 | 0.08040 | 1.0498 | 0.0049 | 1.9926 |
| Iso-Butyraldehyde | 5 | 0.02840 | 2.9385 | 0.0127 | 1.9653 |
| Crotonaldehyde | 5 | 0.04487 | 2.0720 | 0.0096 | 2.1902 |
| Hexanaldehyde | 5 | 0.01497 | 5.3590 | 0.0144 | 1.8898 |
| Benzaldehyde | 5 | 0.06550 | 1.3593 | 0.0104 | 2.0972 |

# THE MEASUREMENT OF SULFUR DIOXIDE USING THE BARIUM CHLORANILATE METHOD
## ($SO_2$-BCA)

February 1975

Southwest Research Institute
San Antonio, Texas

## I. BACKGROUND

The measurement of sulfur dioxide ($SO_2$) in dilute automotive exhaust has been a difficult task. Although there are several continuous recording $SO_2$ instruments commercially available, they have not demonstrated the degree of accuracy necessary at the $SO_2$ levels observed in dilute automotive exhaust. A number of other wet chemical procedures are also available but are considered either excessively time consuming or lacking in sensitivity. With this in mind, an idea was conceived by EPA Research Triangle Park to use some basic concepts in the Federal Register and to adapt these concepts for measuring $SO_2$ in dilute automotive exhaust.

This procedure uses midget impingers with 3 percent hydrogen peroxide to oxidize the $SO_2$ to sulfate. The samples are then evaporated, treated, extracted and analyzed according to the barium chloranilate method for sulfate analysis. The main advantages of this procedure are the sensitivity and the simplicity of analysis.

## II. APPARATUS

This procedure incorporates two midget impingers in series with a 0.5µ filter in the sample line. Other items in the sample train include drierite tube, wet test meter, sample pump and flowmeter. A flow schematic is presented in Figure 1 to illustrate the relative positions of the various individual components. The sample probe is glass and the filter is a 0.5µ SS filter press-fit into the teflon union connecting the glass sample probe and the first bubbler. By use of appropriate valving, a dual system could be assembled if consecutive samples were desired such as in the cold start 505 and the stabilized portion of the 1975 FTP.

A. Midget impingers - capable of handling 25 ml of absorbing reagent.

B. Sample pump - must have sample flow capacity of at least 2 l/m.

C. Drierite column - filled with mixture of indicating and non-indicating drierite.

D. Wet test meter - capable of accurately measuring sample flow rates at least in the range of 2 l/min.

E. Flow meter - capable of monitoring flow rates in the range of 2 l/min.

F. Sample probe - glass should be of minimum length.

G. Filter - 0.5μ stainless steel filter disc press-fit into teflon union.

H. Barium Chloranilate Sulfate Analysis System(1).

## III. REAGENTS

A. 30 percent stabilized hydrogen peroxide ($H_2O_2$) ACS reagent grade. Store in refrigerator.

B. 3 percent hydrogen peroxide solution, dilute 30 percent 10:1 to obtain the required 3 percent $H_2O_2$. Use only distilled water as the dilutent. Prepare the day of use.

C. Ammonium hydroxide, 1M. Use ACS reagent grade diluted to obtain the desired 1M solution.

D. Red litmus paper.

E. Isopropyl alcohol, spectroquality identical to that used in the sulfate analysis.

F. 60 percent IPA - 40 percent $H_2O$, same solvent that is used in the barium chloranilate method for sulfate analysis.

G. Distilled water, used in preparation of absorbing reagent (3 percent $H_2O_2$) and extraction solvent (60 percent IPA).

H. Ammonium sulfate, ACS grade, used in the perparation of ammonium sulfate standards.

I. Miscellaneous analytical and chemical support items, routinely used in the Barium Chloranilate Procedure.

## IV. PREPARATION OF SULFATE STANDARDS (USING $(NH_4)_2SO_4$)

A. Comments

Weigh out exactly 2.750 g of ACS reagent grade $(NH_4)_2SO_4$ into a pre-weighed clean dry beaker. Dissolve the $(NH_4)_2SO_4$ in 60 percent IPA and dilute to a total of 1000 ml in a Class A volumetric flask. The resulting sulfate concentration is then 2000 $\mu g\ SO_4^{=}/ml$. This solution is called the dilute primary standard and is to be used to prepare working calibration standards.

---

(1) Designates that which is attached.

## B. Calculations

$$2.750\ g\ (NH_4)_2SO_4 = 2.750\ g\ (NH_4)_2SO_4 \times \frac{96\ awu\ SO_4^{=}}{132\ awu\ (NH_4)_2SO_4}$$

$$2.750\ g\ (NH_4)_2SO_4 = 2.000\ g\ SO_4 =$$

$$2.000\ g\ SO_4^{=}/1 = 2.000\ g\ SO_4^{=}/1 \times \frac{1\ 1}{1000\ ml} \times \frac{10^6 \mu g}{1\ g}$$

$$2.000\ g\ SO_4^{=}/1 = \frac{2.000 \times 10^6 \mu g}{10^3\ ml} = 2000 \mu g/ml$$

## C. Preparation of Working Standards

| Sample | Volume of Dilute Primary Standard* | Volumetric Flask, ml** | Sulfate Concentration $\mu g\ SO_4^{=}/ml$ |
|---|---|---|---|
| 1 | 10 | 1000 | 20.0 |
| 2 | 15 | 2000 | 15.0 |
| 3 | 5 | 1000 | 10.0 |
| 4 | 5 | 2000 | 5.0 |
| 5 | 1 | 1000 | 2.0 |

---

* Measured using Class A volumetric pipet.

** Measured using Class A volumetric flask.

After each set of standards are prepared, run to establish the validity and linearity of the new working standards.

All glassware should be thoroughly cleaned and no visible glassware spots should be tolerated. Once the working standards are prepared, they should be transferred to clearly marked glass reagent bottles for storage.

## V. PROCEDURE

## A. Sample Acquisition

The exhaust sample to be analyzed is bubbled through the two midget impingers in series. Prior to sampling, it is important to leak check the sampling system to insure no leaks are present. Once the absence of leaks is verified, pipet 25 ml of freshly prepared 3 percent hydrogen peroxide into each of the bubblers. All ground glass fittings should have stopcock grease to insure leak tight connections. Prior to testing, the drierite column is freshly prepared and the wet test meter is read. Once the test has started, the flow is adjusted to 1.5 l/min. Sampling times will vary depending on the concentration of the $SO_2$ in the exhaust sample; however, the extracted sample can be diluted if necessary.

Tests have shown that sufficient sample can be obtained from 10 minutes at 2 to 3 ppm $SO_2$ levels, bubbling at a rate of 1.5 l/min. It might be possible to use somewhat higher sample flow rates if necessary, but high recoveries have been observed at 1.5 l/min. Generally, sampling for periods of more than 20 minutes will require dilution at the 2 to 3 ppm $SO_2$ level. It should be pointed out that this will vary somewhat depending on the range capability of the individual BCA system.

### B. Extraction Procedure

1. After the bubbling is complete, quantitatively transfer the absorbing reagent to a 100 ml beaker. Rinse the impinger tip and bubbler thoroughly several times with 3 percent $H_2O$. Add these rinsings to the original absorbing reagent in the 100 ml beaker. This will bring the total volume to about 30 ml. The final volume at this point is not critical since the absorbing reagent will be evaporated to dryness.

2. Place the 100 ml beaker on a steam bath and begin evaporating. Once the volume has evaporated to about 10 ml, make the solution slightly basic to litmus with 1M ammonium hydroxide. Use a stirring rod tip to touch the sample to a strip of red litmus paper. Usually 2 to 4 drops will be sufficient. Complete the evaporation to dryness to insure that no ammonium hydroxide remains in the beaker. Several experiments in determining recovery rates have indicated that any ammonium hydroxide remaining will create an interference.

3. Once the beaker is thoroughly dry, remove from the steam bath and allow to cool. The entire evaporation procedure requires about 4 to 5 hours per beaker. The ammonium sulfate appears as a white deposit on the bottom and sides of the beaker. Use a rubber policeman on a glass stirring rod with about 2 ml of 60 percent IPA to gently break loose the deposit and put into solution. This step is repeated several times using about 2 ml of 60 percent IPA each time. After each time, add the rinsing to a 10 ml volumetric flask. After a minimum of three extraction-rinsings, dilute to the mark with additional 60 percent IPA. After the sample has been properly prepared, it is then considered ready for analysis in the barium chloranilate system.

## C. Analysis

After the sample has been bubbled, evaporated, treated and extracted, it is analyzed using the barium chloranilate procedure. Since these samples are essentially ammonium sulfate in 60 percent IPA, the working standards are also ammonium sulfate in 60 percent IPA. A copy of the barium chloranilate procedure is attached for reference. Standards are run before and after each sample and blanks are run between all samples and standards. A typical trace of a standard, blank, sample sequence is shown in Figure 2.

## D. Calculations

The equation used to calculate the ppm $SO_2$ in an exhaust sample using the $SO_2$-BCA procedure is listed below:

$$\text{ppm } SO_2 \text{ sample} = \frac{6.67 \times \text{conc } SO_4^{=} \text{ std, } \mu g \times \text{area } SO_4^{=} \text{ sample, in}^2 \times DF}{\text{area } SO_4^{=} \text{ std, in}^2 \times \text{density, g/l} \times \text{sample volume, l}}$$

The derivation of this equation is presented as an attachment and is applicable to this specific procedure.

Although calculations use peak areas, it would be possible to use peak heights under certain conditions:

(Example 1) - Assume an exhaust sample was bubbled through two bubblers in series and a total of 12.75 liters was sampled. The gas entering the dry gas meter was 0° C at a barometric pressure of 29.92" Hg. A $SO_4^{=}$ standard of 19.2 µg/ml gave a response of 1.56 in$^2$. When diluted 5:1 for the first bubbler and left at full strength for the second, the unknown sample gave a response of 2.05 in$^2$ for the first bubbler and 0.32 in$^2$ for the second bubbler.

$$\underset{\text{(bubbler 1)}}{\text{ppm } SO_2} = \frac{6.67 \times 19.2 \times 2.05 \times 5}{1.56 \times 2.927 \times 12.75} = 22.5 \text{ ppm}$$

$$\underset{\text{(bubbler 2)}}{\text{ppm } SO_2} = \frac{6.67 \times 19.2 \times 0.42 \times 1}{1.56 \times 2.927 \times 12.75} = 0.9 \text{ ppm}$$

Total Sample ppm $SO_2$ = 22.5 ppm + 0.9 ppm = 23.4 ppm

(Example 2) - Assume an exhaust sample was bubbled through two bubblers in series and a total of 1.436 ft$^3$ was sampled. The gas entering the dry gas meter was 30° C at a barometric pressure of 29.31" Hg. An $SO_4^{=}$ standard of 9.6 µg $SO_4^{=}$/ml gave a response of 0.78 in$^2$. When diluted 10:1 for the first bubbler and leaving the second at full strength, the unknown sample gave a response of 3.25 in$^2$ for the first bubbler and 0.21 in$^2$

Inspected by aRJ.

for the second bubbler. (Note that there are two differences in the examples, this example has the sample volume in $ft^3$ rather than liters and the sampling conditions are not at STP.) The first calculation will be to obtain the density of $SO_2$ at 30°C and 29.31" Hg.

$$\text{density } SO_2 \text{ at } 0°C \text{ and } 29.92" \text{ Hg} = \frac{2.927 \text{ g}}{1 \text{ l}}$$

1 liter at 0°C and 29.92" Hg = 1.133 liters at 30°C and 29.31" Hg

$$1 \text{ l} = 1 \text{ l} \times \frac{273 + 30°K}{273°K} \times \frac{29.92" \text{ Hg}}{29.31" \text{ Hg}} = 1.133 \text{ l}$$

$$\text{density } SO_2 \text{ at } 30°C \text{ and } 29.31" \text{ Hg} = \frac{2.927 \text{ g}}{1.133 \text{ l}} = 2.583 \text{ g/l}$$

$$\underset{\text{(bubbler 1)}}{\text{ppm } SO_2} = \frac{0.2356 \times 9.6 \times 3.25 \times 10}{0.78 \times 2.583 \times 1.436} = 25.4 \text{ ppm}$$

$$\underset{\text{(bubbler 2)}}{\text{ppm } SO_2} = \frac{0.2356 \times 9.6 \times 1.95 \times 1}{0.78 \times 2.583 \times 1.436} = 1.5 \text{ ppm}$$

Total Sample ppm $SO_2$ = 25.4 + 1.5 = 26.9 ppm

**SOUTHWEST RESEARCH INSTITUTE**
**DATA SHEET**

SUBJECT DERIVATION OF SIMPLIFIED $SO_2$-BCA EQUATION

SHEET NO. 1 OF 2 SHEET
PROJECT 11-4015-001
DATE 2-13-75
BY HARRY E. DIETZMANN

STEP I: (FROM DENSITY = WEIGHT/VOLUME)

$$\text{VOL } SO_2 \text{ SAMPLE}, \mu l = \frac{\text{WEIGHT OF } SO_2 \text{ SAMPLE}, \mu g}{\text{DENSITY } SO_2, g/l}$$

STEP II: (FROM DEFINITION OF PPM)

$$\text{PPM } SO_2 \text{ SAMPLE}, = \frac{\text{VOL } SO_2 \text{ SAMPLE}, \mu l}{\text{SAMPLE VOL}, l}$$

STEP III: (FROM BCA PROCEDURE)

$$\text{CONC. } SO_4^{=} \text{ SAMPLE}, \mu g/ml = \frac{\text{CONC } SO_4^{=} \text{ STD}, \mu g/ml \times \text{AREA } SO_4^{=} \text{ SAMPLE},}{\text{AREA } SO_4^{=} \text{ STD}, IN^2}$$

$$\text{WEIGHT } SO_4^{=} \text{ SAMPLE}, \mu g = \text{CONC } SO_4^{=}, \mu g/ml \times 10\ ml \times \text{D.F.}$$

$$\text{WEIGHT } SO_4^{=} \text{ SAMPLE}, \mu g = \frac{\text{CONC } SO_4^{=} \text{ STD}, \mu g/ml \times \text{AREA } SO_4^{=} \text{ sample}, in^2 \times 10m}{\text{AREA } SO_4^{=} \text{ STD}, IN^2}$$

STEP IV: (66.7% OF $SO_4^{=}$ IS $SO_2$)

$$\text{WEIGHT } SO_2 \text{ SAMPLE}, \mu g = 0.667 \times \text{WEIGHT } SO_4^{=} \text{ SAMPLE}, \mu g$$

$$\text{WEIGHT } SO_2 \text{ SAMPLE}, \mu g = \frac{0.667 \times \text{CONC } SO_4^{=} \text{ STD}, \mu g/ml \times \text{AREA } SO_4^{=} \text{ sample}, in^2 \times 10\ ml \times DF}{\text{AREA } SO_4^{=} \text{ STD}, IN^2}$$

STEP V: (COMBINING STEPS I + IV)

$$\text{VOL } SO_2 \text{ sample}, \mu l = \frac{0.667 \times \text{CONC } SO_4^{=} \text{ STD}, \mu g/ml \times \text{AREA } SO_4^{=} \text{ SAMPLE}, IN^2 \times 10\ ml \times}{\text{AREA } SO_4^{=} \text{ STD}, IN^2 \times \text{DENSITY } SO_2, g/l}$$

P

## SOUTHWEST RESEARCH INSTITUTE
## DATA SHEET

SUBJECT DERIVATION OF SIMPLIFIED $SO_2$ - BCA EQUATION

SHEET NO. 2 OF 2 SHEET:
PROJECT 11-4015-001
DATE 2-13-75
BY HARRY E. DIETZMANN

STEP VI: (COMBINING STEPS II + V)

$$\text{ppm } SO_2 \text{ SAMPLE} = \frac{0.667 \times \text{Conc } SO_4^= \text{ STD}, \mu g/ml \times \text{AREA } SO_4^= \text{ sample}, in^2 \times 10\ ml \times DF}{\text{AREA } SO_4^= \text{ STD}, IN^2 \times \text{DENSITY } SO_2, g/l \times \text{Sample Volume}, l.}$$

STEP VII: (COMBINING CONSTANTS)

$$\text{PPM } SO_2 \text{ SAMPLE} = \frac{6.67 \times \text{Conc } SO_4^= \text{ STD}, \mu g/ml \times \text{AREA } SO_4^= \text{ sample}, in^2 \times DF}{\text{AREA } SO_4^= \text{ STD}, IN^2 \times \text{DENSITY } SO_2, g/l \times \text{Sample Volume}, l}$$

(FOR VOLUMES MEASURED IN LITERS)

$$\text{ppm } SO_2 \text{ SAMPLE} = \frac{0.2356 \times \text{Conc } SO_4^= \text{ STD}, \mu g \times \text{AREA } SO_4^= \text{ sample}, in^2 \times DF}{\text{AREA } SO_4^= \text{ STD}, in^2 \times \text{Density } SO_2, g/l \times \text{Sample Volume}, FT^3}$$

(FOR SAMPLE VOLUMES MEASURED IN $FT^3$)

NOTES:

1. Use $SO_2$ density of 2.927 g/l @ 0°C and 29.92 " Hg
2. Sample volume and $SO_2$ densities should be corrected to the same reference point, i.e. if the temperature of the sample gas at the dry gas meter was 30 °C and the barometer read 28.95, then the density of $SO_2$ at those conditions should be used in the calculations.

PC

Note: All tubing in sample train up to the impingers is glass or teflon.

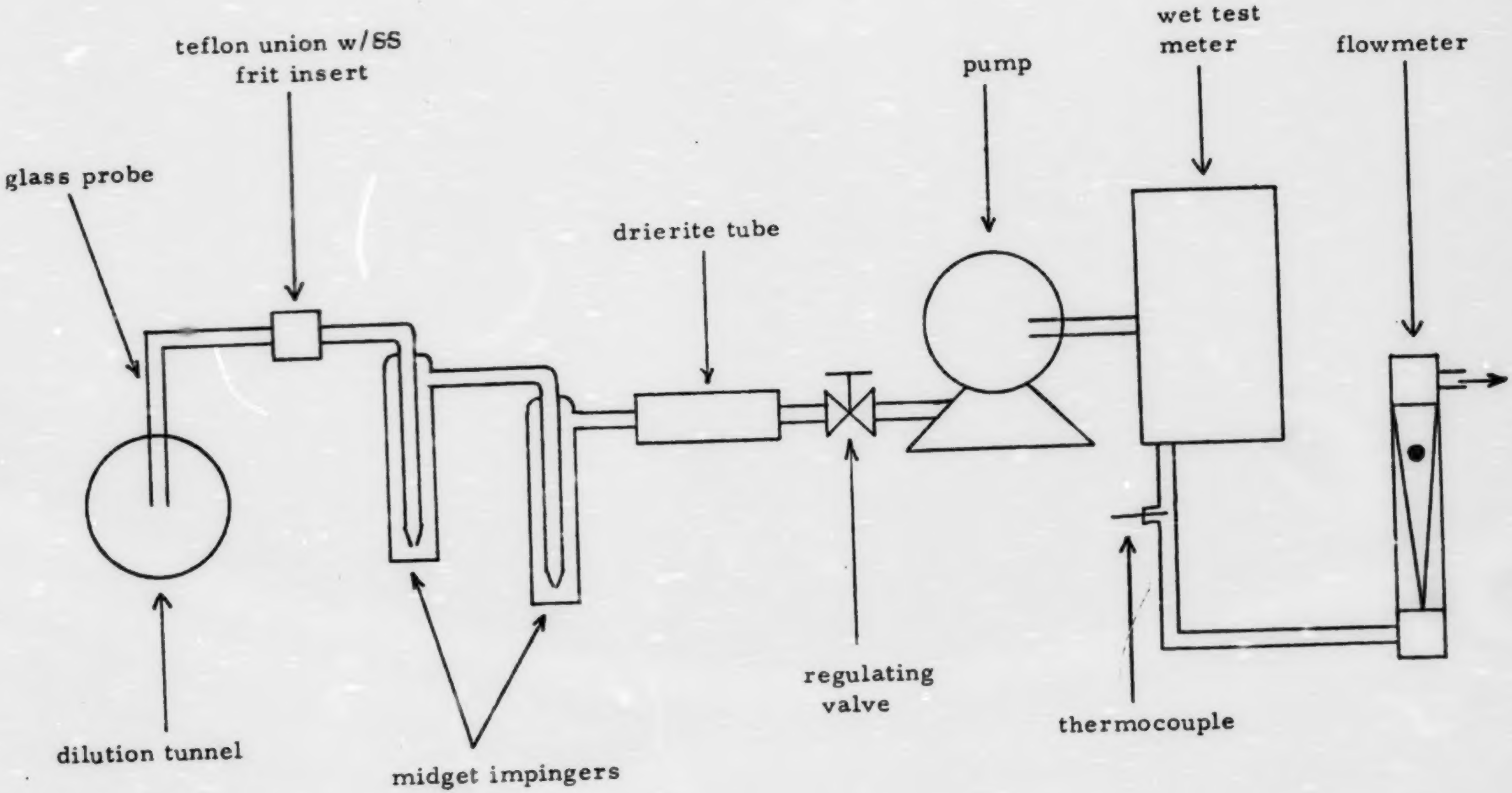

teflon union w/SS frit insert
glass probe
drierite tube
pump
wet test meter
flowmeter
dilution tunnel
midget impingers
regulating valve
thermocouple

FIGURE 1. $SO_2$-BCA FLOW SCHEMATIC

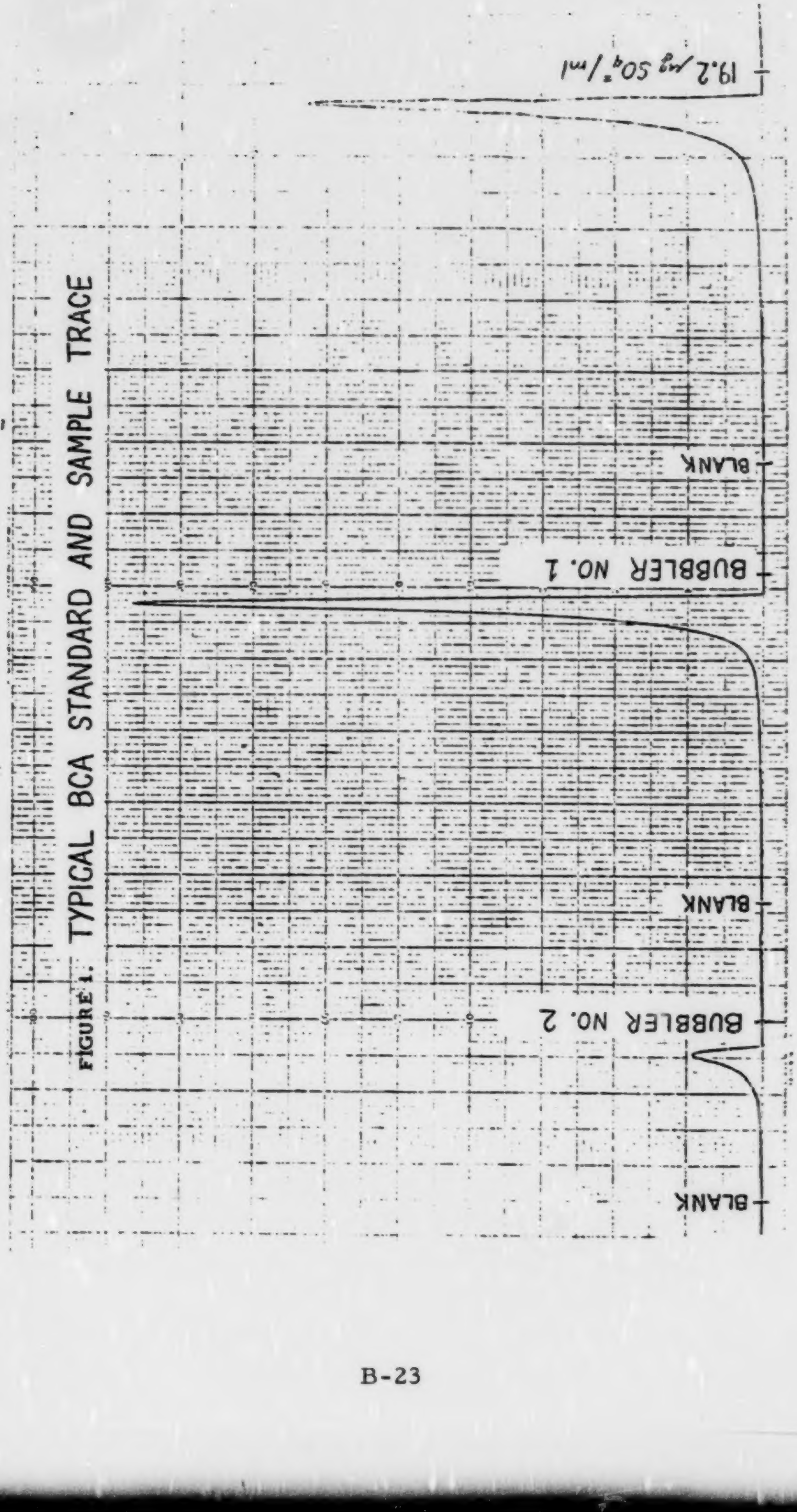


FIGURE 1. TYPICAL BCA STANDARD AND SAMPLE TRACE

June 17, 1975

Dr. R. S. Spindt
Gulf Research and Development Co.
P. O. Drawer 2038
Pittsburgh, Pennsylvania 15230

Dear Dr. Spindt:

In reference to our telephone conversation of June 13, I am sending you the benzene extract of diesel exhaust particulates from a glass fiber filter (8" x 10"). This is one sample of seven submitted to us by Mr. Karl Springer for analysis of benz(α)pyrene. The data are as follows:

| | |
|---|---|
| Batch: | #1 |
| Filter No.: | AR-2003 |
| Condition: | 2100 rpm - 100% load |
| Particulate weight (g): | 0.205837 |
| Extract weight (g): | 0.09770 |
| Total B(α)P extracted (μg): | 50.3 |
| Filter description: | Black; much powder |
| Extract description: | Clear; golden brown |

The analytical procedure used for this work followed that described by Sawicki et al. (Health Lab. Sci. 7(1) Suppl., Jan., 1970) with some minor modifications. In general, the procedure is as follows:

1. Prewash Soxhlet equipment by refluxing benzene for 1 hour.

2. Extract filter by Soxhlet method with benzene (distilled in glass) for 4 hours. (8" x 10" filter divided into measured sections of 4" x 5" to facilitate extraction process. Each filter portion was placed in a separate Soxhlet apparatus and the extracts combined after completion of the process).

3. Evaporate the solvent to a few ml volume and quantitatively transfer to a preweighed vial (this step allows separation of filter fiber residue from the sample). Evaporate the solvent and reweigh the vial to determine the weight of extractable material.

4. Add exactly 1 ml of solvent to the vial and redissolve the residue.

5. Spot 10 μl of this solution on a thin layer plate (alumina or silica gel) and develop with 19:1 hexane ether.

6. Scrape the plate in the region where the B(α)P separates using a high concentration marker as a guide.

7. Dissolve the adsorbed material and quantitatively filter to remove the insoluble particles.

8. Evaporate the filtrate to dryness and add 1 ml $H_2SO_4$.

9. Read the fluorescence intensity with excitation at 470 nm and emission at 540 nm.

10. Known quantities of B(a)P spotted on TLC and extracted were used as comparison standards.

I hope that we may be able to easily solve the apparent variations between our analyses.

It may be beneficial if we were to undertake analyses by one another's procedures, as well as samples, to obtain a better understanding of the complexities involved and, perhaps, to obtain another degree of inter-laboratory comparability.

Should you have materials which have already been analyzed and are suitable for shipment, we would also be interested in undertaking a re-analysis in our laboratory.

If you have any further questions or if I may be of further assistance please call me at 512-674-1410, Ext. 363.

Sincerely yours,

George H. Lee, II, Ph.D.
Associate Foundation Scientist
Department of Environmental Sciences

GHL/pat

cc: Karl Springer
John Rowlands

## 1. Non-Reactive Hydrocarbons (NRHC)

The measurement of NRHC was performed using a gas chromatograph procedure developed by EPA (RTP)(8). This procedure uses a single flame ionization detector with a multiple column arrangement and dual gas sampling valves. The timed sequence selection valves allow for the baseline separation of air, $CH_4$, $C_2H_4$, $C_2H_2$, $C_3H_8$, $C_3H_6$, $C_6H_6$, and $C_7H_8$. Although only $CH_4$, $C_2H_6$, $C_2H_2$, $C_3H_8$, and $C_6H_6$ are considered non-reactive, $C_2H_4$, $C_3H_6$, and $C_7H_8$ were determined during the course of the analysis. Only the non-reactive hydrocarbons are used in the calculation of NRHC emission rates, but all individual hydrocarbon data is useful in the characterization of emissions from the two Chevrolet engines.

Samples were obtained directly from the bag samples of 1975 LD FTP and analyzed in the NRHC system. Individual NRHC values were determined and a NRHC value for the bag was calculated. This value was then used to determine the NRHC emission rates for these tests. By knowing the NRHC and HC emission rates, it was possible to determine the fraction of NRHC in the total HC. A detailed description of the individual columns, temperatures, flow rates, etc. may be found in Reference 8 Figure A-1 illustrates the NRHC analytical instrumentation that was used for this analysis.

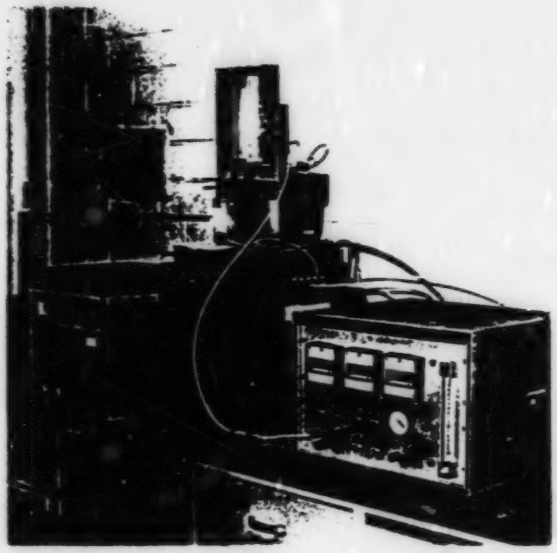


FIGURE A-1. NON-REACTIVE HYDROCARBON GAS CHROMATOGRAPH INSTRUMENTATION

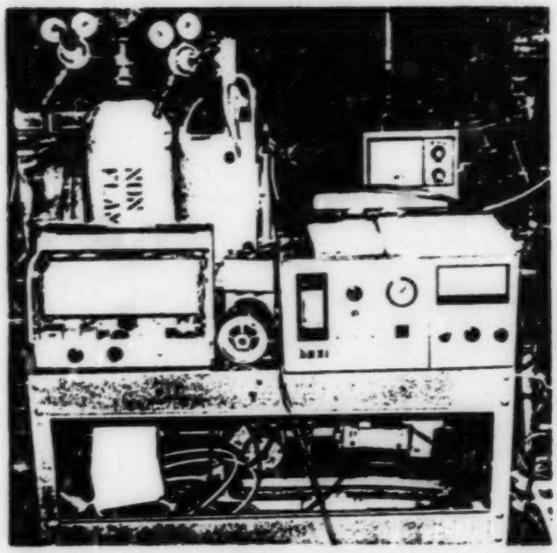


FIGURE A-2. TECO MODEL 40 PULSED FLUORESCENT $SO_2$ ANALYZER

# Determination of Soluble Sulfates: Automated Method

## 1. Principle and Applicability

1.1 This method is for the determination of water-soluble sulfates from diluted automobile exhausts collected on Fluoropore filters. The method is quite general and may be used for trace sulfate analysis of any sample from which sulfates can be leached out with water or aqueous alcoholic solutions. There are interferences from some anions and methods for minimizing or eliminating these are still being worked out. The method as written is applicable to sulfate analysis of exhaust emissions from cars run on non-leaded gasoline.

1.2 Auto exhaust is mixed with air in a dilution tunnel and sampled through isokinetic probes. $SO_3$ reacts with available moisture in the exhaust to form $H_2SO_4$ aerosols and is trapped on Fluoropore* filters with 0.45 μ pore size. The filter is extracted with 60/40 isopropyl alcohol/water solution (i.e. 60 ml isopropyl alcohol (IPA) + 40 ml water). The extract is fed by a high pressure liquid (chromatographic) pump through a column of cation exchange resin to remove cationic interferences and then through a column of solid barium chloranilate where $BaSO_4$ precipitates out. An equivalent amount of reddish colored acid chloranilate ion is released[1,2] and is measured colorimetrically at 310 mμ[3,4]. To use this method for aqueous sulfate solutions, four parts by volume of the solution are mixed with six parts of IPA before feeding through the columns. Manual method or a dynamic sampling system can be used.

*Registered trade mark. Obtainable from Millipore Corp.

## 2. Range and Sensitivity

Working concentration range and sensitivity depend on sample size. A sensitivity better than 0.5 µg $SO_4^{=}$ per ml in 60% IPA and working range of 0 - 25 µg/ml were obtained using a 0.5 ml external sampling loop injection system in conjunction with a du Pont liquid chromatograph UV detector. Sensitivity may be further increased by increasing the alcohol content of the solvent, as this would further decrease the solubility of $BaSO_4$ and barium chloranilate. This, however, requires a much tighter control of the water/IPA ratio in the sample and in the mobile phase. To minimize spurious results arising from water imbalance, it is recommended that both the extracting solvent and the mobile phase for analytical runs be taken from the same stock solution. Sample size as large as 1.5 ml has been successfully used.

## 3. Interferences

Cations interfere negatively by reacting with the acid chloranilate to form insoluble salts. These, however, are conveniently removed by passing the sample through a cation exchange resin in the acid form. Some anions such as $Cl^-$, $Br^-$, $F^-$, $PO_4^{\equiv}$ interfere positively by precipitating out as barium salts with subsequent release of acid chloranilate ions. Some buffer systems [2-5] are reported to minimize anion interference. These systems are being investigated for possible incorporation in the present procedure. Alternative clean-up methods are also under consideration. Fortunately, for non-leaded exhaust samples collected on filters, ionic interference is minimal. Interference from aromatic compounds is minimized by using a 300 mµ cut-off filter in the optical path of the detector system.

## 4. Precision, Accuracy, and Stability

### 4.1 Precision

With an external sampling loop of about 1.5 ml, photometer attenuation set to read .04 absorbance units full scale, standard deviation of 0.05 μg $SO_4^=$/ml was obtained for a sample containing 4.0 μg $SO_4^=$/ml.

### 4.2 Stability

4.2.1 Sulfuric acid standards containing 10 and 100 μg $SO_4^=$/ml in 60% IPA are stable for at least one month when stored in tightly capped volumetric flask which has been cleaned with 1:1 nitric acid and copiously rinsed with deionized water. Alternative storage containers are capped polyethylene reagent bottles.

4.2.2 The cation exchange resin and the barium chloranilate columns as described in apparatus section last for over two months. For samples known to contain cations, it is advisable to remove these cations by external treatment with cation exchange resin prior to injection into the sampling loop.

4.2.3 As the barium chloranilate column is depleted each time sulfate samples are fed through, it is good practice to run sulfuric acid standards before and after the sample.

4.2.4 Exposure of alcoholic samples, standards, and solvents to the atmosphere should be minimized, since IPA solution picks up atmospheric water on standing.

## 5. Apparatus

A schematic of the principal components of the automated set-up is shown in Figure 1.

### 5.1 Hardware

a. Reservoir (LR) for the solvent (60% IPA).

b. High pressure liquid pump (LP) capable of delivering liquids at flow rates of up to 3 ml/min at pressures as high as 1000 psi. Most liquid pumps used in high pressure liquid chromatography would be satisfactory.

c. Flow or pressure controller (FC).

d. Six-port high pressure switching valve (SV) equipped with interchangeable external loop (L).

e. Ultraviolet detector (D) equipped with appropriate filters to isolate a narrow band of radiation centered at 310 mμ. A microscope cover glass was found to be satisfactory.

f. Recorder to monitor detector response.

g. Automatic sampler (AS), such as the one used for a Technicon AutoAnalyzer.

h. Peristaltic pump (PP) to draw sample into sampling loop.

i. Cation exchange resin column (CX) - standard 1/4" O. D. x 10" stainless steel column packed with analytical grade Dowex 50W-X2 cation exchange resin in hydrogen form.

j. Barium chloranilate column (BC) - standard 1/4" O. D. x 5" stainless steel column packed with barium chloranilate.

## 5.2 Principle of Operation

Solvent (60% IPA) in reservoir (LR) is continuously fed through cation exchange (CX) and barium chloranilate columns at flow rates of about 3 ml/min. by a high pressure liquid pump (LP). Background absorbance is continuously measured by a UV detector (D) at 310 mμ and visually monitored in a strip chart recorder. A solenoid actuated air operated switching valve (SV) is used for filling the external sampling loop (L) with samples in conjunction with an automatic sampler (AS) and peristaltic pump (PP) and injecting the sample into the columns. At CX cations are removed and at BC, color reaction takes place. The $BaSO_4$ precipitate is retained in the column while the acid chloranilate is carried by the solvent through the detector system for colorimetric measurement.

For an automated sampling system such as shown in Figure 1, both SV and PP are electrically coupled to AS by electric relays such that both are activated whenever AS is sampling (i.e. L is being filled and mobile phase bypasses L). At the end of the sampling cycle, PP and AS stop and SV switches to the injection mode (i.e. mobile phase passes through L and carries sample through CX and BC columns).

For manual operation SV may be retained or replaced by a similar switching valve equipped with an extended handle for manual switching. Samples may be introduced into the sampling loop by syringe injection or by peristaltic pump system similar to the one used in the automated system.

6. Reagents

6.1 Isopropyl alcohol (IPA) spectroquality grade or equivalent. Volatile solvent, safety class 1B.

6.2 60% IPA. Add four parts water to six parts IPA by volume. Store in tightly capped bottle. About three liters are needed for a 12 hour operation.

6.3 Barium chloranilate, suitable for sulfate analysis.

6.4 Dowex 50W-X2 cation exchange resin, hydrogen form, 100-200 mesh.

6.5 Hydrochloric acid (4N). Add 30 ml concentrated hydrochloric acid to 60 ml deionized water. (Danger, strong acid.)

6.6 Standard sulfuric acid (1N). Dilute to the mark 2.8 ml of concentrated sulfuric acid with deionized distilled water in a liter volumetric flask which has been washed in 1:1 nitric acid and copiously rinsed with deionized distilled water. Standardized against accurately weighed sodium carbonate to get exact normality. 0.1N $H_2SO_4$ is equivalent to 4800 $\mu g/SO_4^{=}/ml$. (Danger, strong acid.)

6.7 Standard sulfate solution (1000 $\mu g\ SO_4^{=}/ml$). Dissolve 1.4787 gm sodium sulfate which has been heated up to 105°C for four hours and cooled in a dessicator and dilute to 1000 ml.

7. Procedure

7.1 Column preparation

7.1.1 Barium chloranilate column (BC). In order to prepare a full column with minimum dead volume connect two lengths of standard 1/4" O. D. stainless steel tubings as shown in Figure 2. b = 2", a = 5". Connect a small funnel to open end of B with a Tygon tubing sleeve.

Fill the funnel half way with barium chloranilate and use a vibrator (i.e. electric pencil engraver) to pack the solid in column. Continue operation until B is about half filled. Remove funnel, plug empty space with glass wool, and cap the end with a 1/4" to 1/16" reducer. Plumb column B directly to SV in Figure 1. Connect a Tygon tubing at A and direct tubing to waste reservoir. Activate liquid pump, set flow controller at pressure drop of about 600 psi. Let solvent flow for 20 minutes. Deactivate pump, disconnect column from SV. Disconnect column A from column B. Connect a glass wool plugged 1/4" to 1/16" reducer to uncapped end of column A.

7.1.2 Cation exchange resin column (CX). Add cation exchange resin, 100-200 mesh, Dowex 50W-X2 to 80 ml of 4N HCl in a 150 ml beaker until a wet volume equivalent to 20 ml has settled at the bottom. Let soak for at least three hours with occasional stirring using a glass rod. Decant the acid, add 100 ml deionized distilled water, stir and slowly decant the liquid as soon as most of the solid has settled down at the bottom. Repeat rinsing procedure several times until rinse liquid gives a neutral reaction to pH paper.

Connect two standard 1/4" O. D. stainless steel tubings as in 7.1.1 with b = 5" and a = 10". Connect a small funnel to open end of B with Teflon or Tygon tubing sleeve. Clamp composite tube vertically and connect open end of A to vacuum line equipped with liquid trap. Fill funnel with deionized distilled water and turn on vacuum slowly until composite tube is completely filled with water. Add water until funnel is half-filled, stop vacuum and add slurry of freshly washed resin. Let resin settle by gravity until resin top is seen above B. Turn on vacuum slowly, keep adding resin slurry until composite tube is completely filled. Proceed as in 7.1.1 beginning with sentence: "Remove funnel, plug empty space..."

### 7.2 Priming System for Analytical Run

Connect the cation exchange and barium chloranilate columns with 1/4" union packed with glass wool as shown in Figure 1. Fill solvent reservoir (LR) with 60% IPA, activate liquid pump, detector, recorder, switching valve, sampler, and peristaltic pump. Allow to cycle normally to clean out all components. For this initial operation, dip the sampling probe in at least 100 ml of 60% IPA. Set liquid flow rate at about 3 ml/min. Let run for at least 30 minutes. Deactivate switching valve, sampler, and peristaltic pump. Leave other components in operating mode. When background is stable at attenuation of .01 absorbance units full scale, system is ready for analysis.

### 7.3 Preparation of Calibration Standards

Either sulfuric acid or sodium sulfate standards may be used.

Add 200 ml of 0.1 N $H_2SO_4$ aqueous stock solution to 300 ml 100% IPA in 500 ml volu[illegible]ic flask. (Note: There is a volume decrease of [illegible]t 2.7% when these proportions of water and IPA are mixed.) Dilute to the mark with 60% IPA. This is equivalent to 1,920 µg $SO_4^=$/ml in 60% IPA. Prepare from this alcoholic stock solution calibration standards in the range 0.5 - 25 µg $SO_4^=$/ml by dilution of appropriate aliquots with 60% IPA.

7.4 Extraction of Soluble Sulfates from Fluoropore Filters

Place filter in one oz. polyethylene bottle, add 10 ml 60% IPA and cap tightly. Shake until filter collapses and is completely immersed in liquid. Let stand overnight.

7.5 Analysis

Set instrument in operating mode, remove sampling probe from holder, and dip in 100 ml 60% IPA. Let it run at flow rate of 3 ml/min until stable background is obtained, then remount sampling probe to holder. In the meantime, fill sample cuvettes with sample extract and blank solutions (60% IPA) and place on turntable. Sampling pattern is blank, blank, sample, blank, blank at the rate of about six minutes per sample or blank. Blanks are used to wash out system between samples and minimize sample overlap. One blank between samples is adequate for dilute samples. (See also 5.2.)

A series of standards (see 7.3) is run, preferably before sample runs and calibration curve, peak height vs. concentration, is plotted. A control standard may also be placed after every ten samples as a quality check on the stability of the system.

The plot of peak height (detector response) vs. concentration (µg $SO_4^=$/ml) is non-linear in the low concentration end as would be expected from solubilities and kinetics consideration. Non-linearity is also observed at the upper end of the curve.

8. Calculations

Calculate the concentration of sulfate as µg $SO_4^=$/ml using the calibration curve. Total soluble sulfates $[SO_4^=]_F$ in filter is then given by:

$$[SO_4^=]_F = (\mu g\ SO_4^=/m) \times Vo \times d$$

where: Vo = total volume of original sample extract
d = dilution factor

Example: Suppose 10 ml 60% IPA was used to extract the soluble sulfates in the filter and that 2 ml of this was diluted further to 6 ml with 60% IPA to bring detector response within calibration range. Suppose that the concentration of the diluted sample was found to be 5 µg/ml. Then,

$$[SO_4^=]_F = (5\ \mu g/ml) \times 10\ ml \times \frac{6}{2} = 150\ \mu g.$$

# References

1. R. J. Bertolacini and J. E. Barney II, "Colorimetric Determination of Sulfate with Barium Chloranilate," Anal. Chem. 29, 281 (1957).

2. Ibid, "Ultraviolet Spectrophotometric Determination of Sulfate, Chloride and Fluoride with Chloranilic Acid," Anal. Chem. 30, 202 (1958).

3. H. N. S. Schafer, "An Improved Spectrophotometric Method for the Determination of Sulfate with Barium Chloranilate as Applied to Coal Ash and Related Materials," Anal. Chem. 39, 1719 (1967).

4. S. C. Barton and H. G. McAdie, "An Automated Instrument for Monitoring Ambient $H_2SO_4$ Aerosol" in Proceedings of the Third International Clean Air Congress, Dusseldorf, Federal Republic of Germany, 1973, VD1-Verlag GmbH, 1973, p. C25.

5. M. E. Gales, Jr., W. H. Kaylor and J. E. Longbottom, "Determination of Sulphate by Automatic Colorimetric Analysis," Analyst 93, 97 (1968).

FIGURE 1

FLOW SCHEMATIC FOR AUTOMATED SULFATE INSTRUMENT

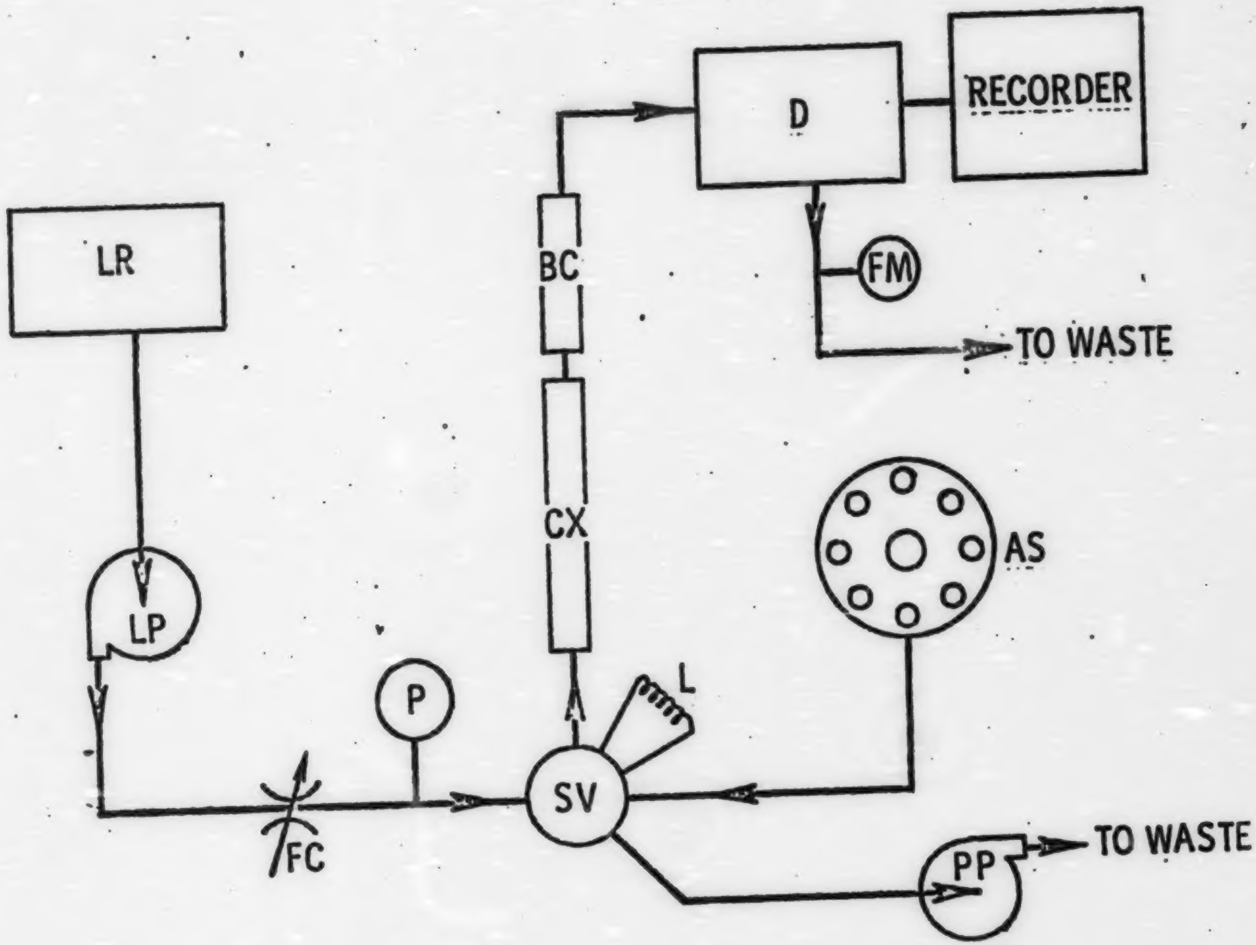
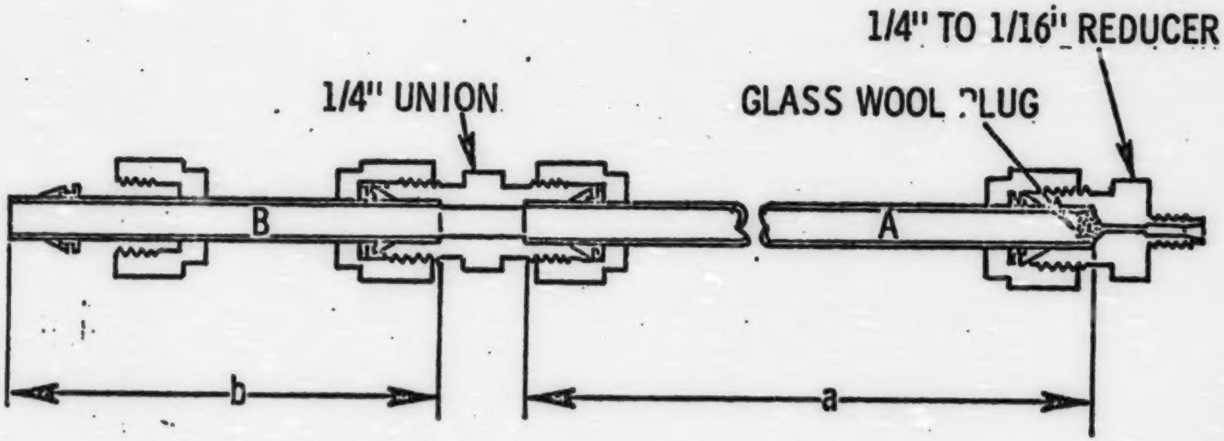

LR
LP
FC
P
SV
L
CX
BC
D
RECORDER
FM
TO WASTE
AS
PP
TO WASTE

FIGURE 2

CONFIGURATION FOR LOADING COLUMN


1/4" TO 1/16" REDUCER
1/4" UNION
GLASS WOOL PLUG
B
A
b
a

# APPENDIX C

# COMPUTER REDUCED 13-MODE FEDERAL TEST RESULTS FOR FIVE HEAVY DUTY ENGINES

TABLE C-1. 13-MODE FEDERAL DIESEL EMISSION CYCLE

DD-AD 6V-71 N COACH ENGINE WITH 60-LSN INJECTORS 1,470 TIMING
TEST 1 RUN 1 3-19-75 1-D FUEL EM-226-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 430 | 4,7 | ,2 | ,023 | 4,50 | 4,52 | ,005 |
| 2 | 1260 | 16,6 | 2,2 | ,064 | 13,59 | 13,66 | ,005 |
| 3 | 1260 | 199,4 | 26,3 | ,132 | 13,92 | 14,05 | ,010 |
| 4 | 1260 | 377,5 | 49,8 | ,204 | 13,46 | 13,66 | ,015 |
| 5 | 1260 | 567,4 | 74,9 | ,283 | 13,46 | 13,74 | ,021 |
| 6 | 1260 | 747,8 | 98,7 | ,412 | 13,88 | 14,29 | ,030 |
| 7 | 430 | 2,4 | ,1 | ,023 | 4,47 | 4,49 | ,005 |
| 8 | 2100 | 641,0 | 140,9 | ,582 | 21,68 | 22,27 | ,027 |
| 9 | 2100 | 474,8 | 104,4 | ,442 | 21,00 | 21,45 | ,021 |
| 10 | 2100 | 325,2 | 71,5 | ,344 | 21,47 | 21,82 | ,016 |
| 11 | 2100 | 156,7 | 34,5 | ,231 | 21,47 | 21,70 | ,011 |
| 12 | 2100 | 9,5 | 2,1 | ,147 | 22,35 | 22,49 | ,007 |
| 13 | 430 | 2,4 | ,1 | ,023 | 4,47 | 4,49 | ,005 |

| MODE | HC PPM | CO+ PPM | NO++ PPM | WEIGHTED KW | BSHC G/KW HR | BSCO+ G/KW HR | BSNO2++ G/KW HR | HUM, MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 393 | 139 | 201 | ,01 | 241,83 | 170,11 | 405,34 | 8,0 |
| 2 | 248 | 153 | 126 | ,18 | 44,95 | 55,09 | 74,81 | 8,0 |
| 3 | 267 | 91 | 345 | 2,10 | 4,15 | 2,82 | 17,55 | 8,0 |
| 4 | 276 | 78 | 623 | 3,98 | 2,20 | 1,23 | 16,27 | 8,0 |
| 5 | 356 | 96 | 1013 | 5,99 | 1,90 | 1,03 | 17,71 | 8,0 |
| 6 | 572 | 3232 | 1128 | 7,89 | 2,41 | 27,14 | 15,56 | 8,0 |
| 7 | 384 | 126 | 194 | ,01 | 469,37 | 306,83 | 776,62 | 8,3 |
| 8 | 400 | 764 | 1037 | 11,27 | 1,84 | 7,00 | 15,60 | 8,3 |
| 9 | 296 | 134 | 816 | 8,35 | 1,77 | 1,60 | 15,96 | 8,3 |
| 10 | 276 | 116 | 550 | 5,72 | 2,45 | 2,04 | 15,97 | 8,3 |
| 11 | 268 | 104 | 282 | 2,76 | 4,91 | 3,81 | 16,93 | 8,3 |
| 12 | 288 | 118 | 135 | ,17 | 90,29 | 73,59 | 138,18 | 8,3 |
| 13 | 336 | 111 | 225 | ,01 | 410,70 | 271,15 | 898,66 | 8,3 |

CYCLE COMPOSITE BSHC = 2,967 GRAM/KW HR
BSCO+ = 7,723 GRAM/KW HR
BSNO2++= 17,171 GRAM/KW HR
BSHC + BSNO2++= 20,138 GRAM/KW HR
BSFC = ,287KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10,7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-2 13-MODE FEDERAL DIESEL EMISSION CYCLE

DD-AD 6V-71 N COACH ENGINE WITH 60-LSN INJECTORS 1,470 TIMING
TEST 1 RUN 2 3-20-75 1-D FUEL EM-226-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 440 | 2,4 | ,1 | ,023 | 4,59 | 4,61 | ,005 |
| 2 | 1260 | 2,4 | ,3 | ,060 | 13,84 | 13,90 | ,004 |
| 3 | 1260 | 197,0 | 26,0 | ,132 | 13,37 | 13,50 | ,010 |
| 4 | 1260 | 389,3 | 51,4 | ,204 | 13,15 | 13,36 | ,016 |
| 5 | 1260 | 584,0 | 77,0 | ,289 | 12,90 | 13,19 | ,022 |
| 6 | 1260 | 778,6 | 102,7 | ,411 | 13,28 | 13,69 | ,031 |
| 7 | 440 | 4,7 | ,2 | ,023 | 4,58 | 4,60 | ,005 |
| 8 | 2100 | 650,4 | 143,0 | ,582 | 21,76 | 22,34 | ,027 |
| 9 | 2100 | 491,4 | 108,1 | ,455 | 21,41 | 21,87 | ,021 |
| 10 | 2100 | 332,3 | 73,1 | ,346 | 21,48 | 21,82 | ,016 |
| 11 | 2100 | 156,7 | 34,5 | ,227 | 21,34 | 21,57 | ,011 |
| 12 | 2100 | 4,7 | 1,0 | ,149 | 21,96 | 22,11 | ,007 |
| 13 | 440 | 2,4 | ,1 | ,023 | 4,57 | 4,59 | ,005 |

| MODE | HC PPM | CO+ PPM | NO++ PPM | WEIGHTED KW | BSHC G/KW HR | BSCO+ G/KW HR | BSNO2++ G/KW HR | HUM, MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 290 | 132 | 225 | ,01 | 356,08 | 322,33 | 904,97 | 8,9 |
| 2 | 244 | 163 | 112 | ,03 | 315,12 | 419,88 | 472,97 | 8,9 |
| 3 | 264 | 78 | 382 | 2,08 | 3,99 | 2,36 | 18,91 | 8,9 |
| 4 | 236 | 64 | 702 | 4,11 | 1,79 | ,96 | 17,39 | 8,9 |
| 5 | 308 | 96 | 1128 | 6,16 | 1,53 | ,95 | 18,39 | 9,3 |
| 6 | 508 | 3152 | 1158 | 8,22 | 1,97 | 24,36 | 14,70 | 9,3 |
| 7 | 300 | 152 | 226 | ,01 | 183,57 | 185,49 | 453,27 | 9,3 |
| 8 | 380 | 670 | 1096 | 11,44 | 1,73 | 6,06 | 16,31 | 9,3 |
| 9 | 292 | 127 | 838 | 8,64 | 1,72 | 1,49 | 16,16 | 9,3 |
| 10 | 252 | 129 | 527 | 5,85 | 2,19 | 2,23 | 14,99 | 9,3 |
| 11 | 236 | 111 | 249 | 2,76 | 4,30 | 4,02 | 14,83 | 9,3 |
| 12 | 252 | 125 | 136 | ,08 | 155,29 | 153,90 | 274,48 | 9,3 |
| 13 | 336 | 132 | 217 | ,01 | 410,41 | 320,43 | 868,19 | 9,3 |

CYCLE COMPOSITE BSHC = 2,626 GRAM/KW HR
BSCO+ = 7,128 GRAM/KW HR
BSNO2++= 17,290 GRAM/KW HR
BSHC + BSNO2++= 19,917 GRAM/KW HR
BSFC = ,283KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10,7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-3 13-MODE FEDERAL DIESEL EMISSION CYCLE

DD-AD 6V-71 N COACH ENGINE WITH 60-LSN INJECTORS 1.470 TIMING
TEST 1 RUN 3 3-20-75 1-D FUEL EM-226-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 440 | 2.4 | .1 | .023 | 4.53 | 4.55 | .005 |
| 2 | 1260 | 2.4 | .3 | .049 | 13.56 | 13.61 | .004 |
| 3 | 1260 | 189.9 | 25.1 | .132 | 13.56 | 13.69 | .010 |
| 4 | 1260 | 384.6 | 50.7 | .204 | 13.56 | 13.77 | .015 |
| 5 | 1260 | 588.7 | 77.7 | .295 | 13.31 | 13.60 | .022 |
| 6 | 1260 | 778.6 | 102.7 | .408 | 13.47 | 13.88 | .030 |
| 7 | 440 | 2.4 | .1 | .023 | 4.50 | 4.52 | .005 |
| 8 | 2100 | 650.4 | 143.0 | .586 | 21.30 | 21.89 | .028 |
| 9 | 2100 | 486.7 | 107.0 | .446 | 21.43 | 21.88 | .021 |
| 10 | 2100 | 325.2 | 71.5 | .333 | 21.56 | 21.90 | .015 |
| 11 | 2100 | 161.4 | 35.5 | .231 | 21.63 | 21.87 | .011 |
| 12 | 2100 | 4.7 | 1.0 | .147 | 22.04 | 22.19 | .007 |
| 13 | 440 | 2.4 | .1 | .023 | 4.49 | 4.51 | .005 |

| MODE | HC PPM | CO+ PPM | NO++ PPM | WEIGHTED KW | BSHC G/KW HR | BSCO+ G/KW HR | BSNO2++ G/KW HR | HUM, MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 336 | 118 | 233 | .01 | 407.04 | 285.04 | 923.63 | 8.8 |
| 2 | 242 | 159 | 119 | .03 | 306.06 | 399.56 | 494.01 | 8.8 |
| 3 | 264 | 100 | 359 | 2.00 | 4.20 | 3.15 | 18.69 | 8.8 |
| 4 | 292 | 77 | 657 | 4.06 | 2.31 | 1.22 | 16.98 | 8.8 |
| 5 | 352 | 99 | 1072 | 6.21 | 1.79 | 1.00 | 17.87 | 8.8 |
| 6 | 492 | 3256 | 1156 | 8.22 | 1.93 | 25.51 | 14.88 | 8.8 |
| 7 | 296 | 144 | 199 | .01 | 356.24 | 346.35 | 783.46 | 8.8 |
| 8 | 388 | 816 | 1040 | 11.44 | 1.73 | 7.24 | 15.16 | 8.8 |
| 9 | 308 | 165 | 844 | 8.56 | 1.83 | 1.96 | 16.43 | 9.4 |
| 10 | 248 | 103 | 526 | 5.72 | 2.21 | 1.83 | 15.34 | 9.4 |
| 11 | 232 | 104 | 281 | 2.84 | 4.16 | 3.72 | 16.48 | 9.4 |
| 12 | 252 | 118 | 126 | .08 | 155.85 | 144.86 | 255.68 | 9.4 |
| 13 | 260 | 119 | 217 | .01 | 311.90 | 281.95 | 850.37 | 9.4 |

CYCLE COMPOSITE BSHC = 2.710 GRAM/KW HR
BSCO+ = 7.657 GRAM/KW HR
BSNO2++= 17.095 GRAM/KW HR
BSHC + BSNO2++= 19.805 GRAM/KW HR
BSFC = .282KG/KW HR

+ CONVERTED TO WET BASIS

++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-4 13-MODE FEDERAL DIESEL EMISSION CYCLE

DD-AD 6V-71 N COACH ENGINE WITH B-60E INJECTORS 1,500 TIMING
TEST 2 RUN 1 3-24-75 1-D FUEL EM-226-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 440 | 2,4 | ,1 | ,023 | 4,56 | 4,58 | ,005 |
| 2 | 1260 | 2,4 | ,3 | ,063 | 13,26 | 13,32 | ,005 |
| 3 | 1260 | 185,2 | 24,4 | ,123 | 13,64 | 13,76 | ,009 |
| 4 | 1260 | 375,1 | 49,5 | ,203 | 13,55 | 13,75 | ,015 |
| 5 | 1260 | 557,9 | 73,6 | ,283 | 13,13 | 13,41 | ,022 |
| 6 | 1260 | 740,7 | 97,7 | ,393 | 13,34 | 13,73 | ,029 |
| 7 | 440 | 2,4 | ,1 | ,023 | 4,53 | 4,55 | ,005 |
| 8 | 2100 | 622,0 | 136,8 | ,559 | 21,75 | 22,31 | ,026 |
| 9 | 2100 | 470,0 | 103,4 | ,446 | 21,61 | 22,06 | ,021 |
| 10 | 2100 | 311,0 | 68,4 | ,334 | 21,35 | 21,68 | ,016 |
| 11 | 2100 | 161,4 | 35,5 | ,238 | 21,42 | 21,66 | ,011 |
| 12 | 2100 | 2,4 | ,5 | ,151 | 21,75 | 21,91 | ,007 |
| 13 | 440 | 2,4 | ,1 | ,023 | 4,53 | 4,55 | ,005 |

| MODE | HC PPM | CO* PPM | NO** PPM | WEIGHTED KW | BSHC G/KW HR | BSCO* G/KW HR | BSNO2** G/KW HR | HUM, MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 88 | 107 | 124 | ,01 | 107,20 | 258,56 | 495,75 | 2,1 |
| 2 | 168 | 254 | 62 | ,03 | 207,97 | 625,58 | 249,53 | 2,1 |
| 3 | 116 | 158 | 188 | 1,95 | 1,90 | 5,18 | 10,10 | 2,1 |
| 4 | 79 | 78 | 355 | 3,96 | ,64 | 1,26 | 9,39 | 2,4 |
| 5 | 84 | 90 | 649 | 5,89 | ,45 | ,95 | 11,27 | 2,4 |
| 6 | 160 | 1348 | 988 | 7,82 | ,65 | 10,98 | 13,22 | 2,4 |
| 7 | 152 | 106 | 124 | ,01 | 183,95 | 256,74 | 491,26 | 2,4 |
| 8 | 169 | 373 | 780 | 10,94 | ,80 | 3,53 | 12,12 | 2,4 |
| 9 | 112 | 116 | 528 | 8,27 | ,70 | 1,43 | 10,74 | 2,4 |
| 10 | 89 | 85 | 280 | 5,47 | ,82 | 1,56 | 8,47 | 2,4 |
| 11 | 88 | 105 | 150 | 2,84 | 1,56 | 3,72 | 8,74 | 2,4 |
| 12 | 236 | 193 | 58 | ,04 | 288,21 | 470,49 | 230,93 | 2,7 |
| 13 | 188 | 133 | 128 | ,01 | 227,51 | 320,77 | 507,67 | 2,7 |

CYCLE COMPOSITE BSHC = 1,238 GRAM/KW HR
BSCO* = 4,606 GRAM/KW HR
BSNO2** = 11,561 GRAM/KW HR
BSHC + BSNO2** = 12,799 GRAM/KW HR
BSFC = ,290KG/KW HR

* CONVERTED TO WET BASIS
** CONVERTED TO WET BASIS AND CORRECTED TO 10,7 MILLIGRAMS WATER PER KG DRY AIR

## TABLE C-5 13-MODE FEDERAL DIESEL EMISSION CYCLE

DD-AD 6V-71 N COACH ENGINE WITH B-60E INJECTORS 1.500 TIMING
TEST 2 RUN 2 3-24-75 1-D FUEL EM-226-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 440 | 2.4 | .1 | .023 | 4.88 | 4.90 | .005 |
| 2 | 1260 | 2.4 | .3 | .060 | 13.97 | 14.03 | .004 |
| 3 | 1260 | 185.2 | 24.4 | .127 | 13.97 | 14.10 | .009 |
| 4 | 1260 | 377.5 | 49.8 | .204 | 13.92 | 14.13 | .015 |
| 5 | 1260 | 557.9 | 73.6 | .280 | 13.46 | 13.74 | .021 |
| 6 | 1260 | 745.4 | 98.3 | .393 | 13.55 | 13.94 | .029 |
| 7 | 440 | 4.7 | .2 | .023 | 4.78 | 4.80 | .005 |
| 8 | 2100 | 622.0 | 136.8 | .559 | 21.90 | 22.46 | .026 |
| 9 | 2100 | 465.3 | 102.3 | .441 | 21.76 | 22.20 | .020 |
| 10 | 2100 | 315.7 | 69.4 | .340 | 21.76 | 22.10 | .016 |
| 11 | 2100 | 159.1 | 35.0 | .234 | 21.42 | 21.66 | .011 |
| 12 | 2100 | 7.1 | 1.6 | .147 | 22.24 | 22.38 | .007 |
| 13 | 440 | 2.4 | .1 | .023 | 4.78 | 4.80 | .005 |

| MODE | HC PPM | CO* PPM | NO** PPM | WEIGHTED KW | BSHC G/KW HR | BSCO* G/KW HR | BSNO2** G/KW HR | HUM, MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 166 | 119 | 124 | .01 | 216.59 | 310.37 | 529.53 | 2.4 |
| 2 | 184 | 227 | 64 | .03 | 239.85 | 589.79 | 274.33 | 2.4 |
| 3 | 152 | 158 | 191 | 1.95 | 2.55 | 5.30 | 10.47 | 2.4 |
| 4 | 84 | 78 | 367 | 3.98 | .69 | 1.29 | 9.90 | 2.4 |
| 5 | 98 | 90 | 702 | 5.89 | .53 | .97 | 12.49 | 2.5 |
| 6 | 168 | 1464 | 1002 | 7.87 | .69 | 12.03 | 13.53 | 2.5 |
| 7 | 112 | 107 | 131 | .01 | 71.56 | 135.61 | 273.07 | 2.5 |
| 8 | 168 | 360 | 809 | 10.94 | .80 | 3.43 | 12.65 | 1.9 |
| 9 | 96 | 98 | 517 | 8.18 | .61 | 1.23 | 10.69 | 1.9 |
| 10 | 75 | 72 | 299 | 5.55 | .69 | 1.34 | 9.06 | 1.9 |
| 11 | 136 | 105 | 145 | 2.80 | 2.45 | 3.78 | 8.57 | 2.0 |
| 12 | 252 | 186 | 58 | .13 | 104.82 | 154.03 | 78.72 | 2.0 |
| 13 | 178 | 113 | 124 | .01 | 227.47 | 286.53 | 519.35 | 2.0 |

CYCLE COMPOSITE BSHC = 1.357 GRAM/KW HR
BSCO* = 4.686 GRAM/KW HR
BSNO2** = 12.008 GRAM/KW HR
BSHC + BSNO2** = 13.365 GRAM/KW HR
BSFC = .288KG/KW HR

* CONVERTED TO WET BASIS
** CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-6 13-MODE FEDERAL DIESEL EMISSION CYCLE

NTC-290 CUMMINS ENGINE WITH TIMING RETARD MODES 3,4,5,6,8,9,10, AND 11
TEST 1 RUN 1 5-14-75 FUEL EM-229-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 610 | 4.7 | .3 | .017 | 4.94 | 4.95 | .004 |
| 2 | 1400 | 4.7 | .7 | .072 | 10.66 | 10.74 | .007 |
| 3 | 1400 | 275.4 | 40.4 | .189 | 10.68 | 10.87 | .018 |
| 4 | 1400 | 562.6 | 82.5 | .367 | 12.23 | 12.59 | .030 |
| 5 | 1400 | 819.0 | 120.1 | .507 | 13.56 | 14.07 | .037 |
| 6 | 1400 | 1125.2 | 164.9 | .658 | 14.90 | 15.56 | .044 |
| 7 | 610 | 19.0 | 1.2 | .017 | 4.92 | 4.93 | .004 |
| 8 | 2100 | 982.8 | 216.1 | .939 | 26.52 | 27.46 | .035 |
| 9 | 2100 | 735.9 | 161.8 | .748 | 24.96 | 25.70 | .030 |
| 10 | 2100 | 493.8 | 108.6 | .567 | 20.54 | 21.11 | .028 |
| 11 | 2100 | 239.8 | 52.7 | .325 | 17.36 | 17.69 | .019 |
| 12 | 2100 | 7.1 | 1.6 | .172 | 15.80 | 15.97 | .011 |
| 13 | 610 | 2.4 | .2 | .017 | 4.92 | 4.93 | .004 |

| MODE | HC PPM | CO+ PPM | NO++ PPM | WEIGHTED KW | BSHC G/KW HR | BSCO+ G/KW HR | BSNO2++ G/KW HR | HUM. MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 238 | 145 | 50 | .02 | 113.11 | 137.27 | 78.10 | 8.4 |
| 2 | 212 | 218 | 66 | .06 | 95.17 | 194.95 | 96.63 | 8.4 |
| 3 | 170 | 145 | 209 | 3.23 | 1.33 | 2.26 | 5.35 | 8.4 |
| 4 | 206 | 208 | 259 | 6.60 | .92 | 1.84 | 3.77 | 8.6 |
| 5 | 198 | 300 | 447 | 9.60 | .68 | 2.04 | 4.99 | 8.6 |
| 6 | 162 | 673 | 706 | 13.20 | .44 | 3.68 | 6.34 | 7.5 |
| 7 | 282 | 154 | 90 | .08 | 33.37 | 36.31 | 34.79 | 7.5 |
| 8 | 88 | 197 | 643 | 17.29 | .32 | 1.45 | 7.78 | 7.5 |
| 9 | 92 | 163 | 437 | 12.95 | .43 | 1.50 | 6.61 | 7.7 |
| 10 | 140 | 202 | 284 | 8.69 | .79 | 2.27 | 5.26 | 7.7 |
| 11 | 152 | 154 | 262 | 4.22 | 1.48 | 3.00 | 8.38 | 7.7 |
| 12 | 226 | 182 | 143 | .13 | 67.07 | 107.91 | 139.23 | 7.9 |
| 13 | 282 | 167 | 87 | .01 | 266.99 | 314.35 | 269.54 | 7.9 |

CYCLE COMPOSITE BSHC = .899 GRAM/KW HR
BSCO+ = 2.600 GRAM/KW HR
BSNO2++= 6.638 GRAM/KW HR
BSHC + BSNO2++= 7.537 GRAM/KW HR
BSFC = .289KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-7 13-MODE FEDERAL DIESEL EMISSION CYCLE

NTC-290 CUMMINS ENGINE WITH TIMING RETARD MODES 3,4,5,6,8,9,10,AND 11
TEST 1 RUN 2 5-14-75 FUEL EM-229-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 610 | 0.0 | 0.0 | .017 | 4.94 | 4.95 | .004 |
| 2 | 1400 | 2.4 | .3 | .072 | 10.79 | 10.86 | .007 |
| 3 | 1400 | 282.5 | 41.4 | .197 | 10.74 | 10.93 | .018 |
| 4 | 1400 | 567.4 | 83.2 | .363 | 12.43 | 12.80 | .029 |
| 5 | 1400 | 814.2 | 119.4 | .495 | 13.80 | 14.30 | .036 |
| 6 | 1400 | 1125.2 | 164.9 | .658 | 14.85 | 15.50 | .044 |
| 7 | 610 | 9.5 | .6 | .017 | 4.92 | 4.94 | .004 |
| 8 | 2100 | 982.8 | 216.1 | .940 | 26.66 | 27.60 | .035 |
| 9 | 2100 | 735.9 | 161.8 | .748 | 25.41 | 26.16 | .029 |
| 10 | 2100 | 489.0 | 107.5 | .575 | 21.28 | 21.86 | .027 |
| 11 | 2100 | 246.9 | 54.3 | .325 | 18.02 | 18.34 | .018 |
| 12 | 2100 | 7.1 | 1.6 | .172 | 15.39 | 15.56 | .011 |
| 13 | 610 | 2.4 | .2 | .017 | 4.90 | 4.91 | .004 |

| MODE | HC PPM | CO+ PPM | NO++ PPM | WEIGHTED KW | BSHC G/KW HR | BSCO+ G/KW HR | BSNO2++ G/KW HR | HUM, MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 285 | 159 | 86 | 0.00 | R | R | R | 8.2 |
| 2 | 265 | 202 | 82 | .03 | 240.70 | 364.73 | 243.31 | 8.2 |
| 3 | 140 | 128 | 242 | 3.31 | 1.08 | 1.96 | 6.08 | 8.2 |
| 4 | 144 | 176 | 303 | 6.65 | .64 | 1.57 | 4.44 | 7.7 |
| 5 | 134 | 249 | 473 | 9.55 | .47 | 1.73 | 5.40 | 7.7 |
| 6 | 90 | 609 | 699 | 13.20 | .25 | 3.32 | 6.26 | 7.7 |
| 7 | 230 | 118 | 101 | .04 | 54.53 | 55.92 | 78.74 | 9.1 |
| 8 | 98 | 173 | 628 | 17.29 | .36 | 1.28 | 7.64 | 9.1 |
| 9 | 98 | 150 | 452 | 12.95 | .46 | 1.41 | 6.96 | 9.1 |
| 10 | 126 | 151 | 279 | 8.60 | .75 | 1.78 | 5.40 | 9.1 |
| 11 | 114 | 103 | 269 | 4.34 | 1.12 | 2.01 | 8.64 | 7.7 |
| 12 | 176 | 152 | 126 | .13 | 50.88 | 87.30 | 119.03 | 7.7 |
| 13 | 264 | 159 | 95 | .01 | 248.98 | 298.51 | 294.14 | 7.7 |

CYCLE COMPOSITE BSHC = .784 GRAM/KW HR
BSCO+ = 2.249 GRAM/KW HR
BSNO2++= 6.841 GRAM/KW HR
BSHC + BSNO2++= 7.625 GRAM/KW HR
BSFC = .289KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-8 13-MODE FEDERAL DIESEL EMISSION CYCLE

NTC-290 CUMMINS ENGINE WITH STANDARD TIMING 0,055 LIFT AT 0,2032 PISTON
TEST 2 RUN 1 6-26-75 FUEL EM-229-F PROJECT: 11-4016-001 INJ,203

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 620 | 4,7 | ,3 | ,026 | 4,37 | 4,39 | ,006 |
| 2 | 1400 | 4,7 | ,7 | ,073 | 10,30 | 10,37 | ,007 |
| 3 | 1400 | 280,1 | 41,1 | ,189 | 10,71 | 10,90 | ,018 |
| 4 | 1400 | 560,2 | 82,1 | ,336 | 11,56 | 11,90 | ,029 |
| 5 | 1400 | 942,7 | 123,5 | ,484 | 13,02 | 13,51 | ,037 |
| 6 | 1400 | 1137,1 | 166,7 | ,635 | 14,42 | 15,05 | ,044 |
| 7 | 620 | 4,7 | ,3 | ,023 | 4,19 | 4,21 | ,005 |
| 8 | 2100 | 1008,9 | 221,8 | ,869 | 25,14 | 26,01 | ,035 |
| 9 | 2100 | 757,3 | 166,5 | ,688 | 22,23 | 22,91 | ,031 |
| 10 | 2100 | 503,3 | 110,7 | ,510 | 19,84 | 20,35 | ,026 |
| 11 | 2100 | 256,4 | 56,4 | ,333 | 17,82 | 18,16 | ,019 |
| 12 | 2100 | 4,7 | 1,0 | ,170 | 16,15 | 16,32 | ,011 |
| 13 | 620 | 2,4 | ,2 | ,026 | 4,43 | 4,45 | ,006 |

| MODE | HC PPM | CO+ PPM | NO++ PPM | WEIGHTED KW | BSHC G/KW HR | BSCO+ G/KW HR | BSNO2++ G/KW HR | HUM, MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 102 | 118 | 119 | ,02 | 42,30 | 97,12 | 161,10 | 10,4 |
| 2 | 78 | 157 | 149 | ,06 | 33,82 | 135,68 | 211,22 | 10,4 |
| 3 | 48 | 115 | 365 | 3,29 | ,37 | 1.77 | 9,22 | 10,4 |
| 4 | 52 | 150 | 726 | 6,57 | ,22 | 1,26 | 10,02 | 10,4 |
| 5 | 61 | 247 | 1337 | 9,88 | ,19 | 1,56 | 13,92 | 10,9 |
| 6 | 59 | 890 | 1865 | 13,34 | ,16 | 4.66 | 16.04 | 10,9 |
| 7 | 119 | 112 | 123 | ,02 | 47,29 | 88,50 | 160.09 | 10,9 |
| 8 | 62 | 128 | 1691 | 17,75 | ,21 | ,87 | 18,89 | 10,9 |
| 9 | 51 | 137 | 1241 | 13,32 | ,20 | 1,09 | 16,27 | 10,6 |
| 10 | 62 | 88 | 717 | 8,85 | ,33 | ,93 | 12,55 | 10,6 |
| 11 | 62 | 79 | 413 | 4,51 | ,58 | 1,48 | 12,68 | 10,6 |
| 12 | 87 | 104 | 204 | ,08 | 39,59 | 94,20 | 303,81 | 10,6 |
| 13 | 126 | 105 | 122 | ,01 | 105,94 | 175,70 | 336,03 | 10,6 |

CYCLE COMPOSITE BSHC = ,345 GRAM/KW HR
BSCO+ = 2,030 GRAM/KW HR
BSNO2++= 15,638 GRAM/KW HR
BSHC + BSNO2++= 15,983 GRAM/KW HR
BSFC = ,269KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10,7 MILLIGRAMS WATER PER KG DRY AIR

```
TABLE C-9   13-MODE FEDERAL DIESEL EMISSION CYCLE

     NTC-290  CUMMINS  ENGINE WITH STANDARD TIMING 0,055 LIFT AT 0,2032 PISTON
     TEST 2 RUN 2   6-26-75      FUEL EM-229-F      PROJECT: 11-4016-001  INJ,203
-----------------------------------------------------------------
MODE  ENGINE  TORQUE  POWER    FUEL     AIR    EXHAUST  FUEL
      SPEED                    FLOW     FLOW    FLOW     AIR
       RPM     N X M     KW   KG/MIN   KG/MIN  KG/MIN   RATIO
-----------------------------------------------------------------
  1     620      2,4     ,2    ,023     4,33    4,35    ,005
  2    1400      4,7     ,7    ,070     8,33    8,40    ,008
  3    1400    277,7   40,7    ,189    10,18   10,37    ,019
  4    1400    562,6   82,5    ,342    11,36   11,70    ,030
  5    1400    840,4  123,2    ,478    12,52   13,00    ,038
  6    1400   1130,0  165,6    ,646    14,11   14,76    ,046
  7     620      4,7     ,3    ,029     4,11    4,14    ,007
  8    2100   1006,5  221,3    ,877    24,28   25,15    ,036
  9    2100    757,3  166,5    ,692    21,65   22,34    ,032
 10    2100    505,6  111,2    ,511    19,43   19,94    ,026
 11    2100    256,4   56,4    ,333    17,44   17,77    ,019
 12    2100      4,7    1,0    ,193    15,50   15,69    ,012
 13     620      2,4     .2    ,026     4,33    4,35    ,006
-------------------------------------------------------------------------
MODE    HC        CO+     NO++   WEIGHTED  BSHC      BSCO+     BSNO2++   HUM,
                                                                      MILLI
        PPM       PPM     PPM       KW    G/KW HR   G/KW HR   G/KW HR   G/KG
-------------------------------------------------------------------------
  1     130       105     130      ,01    106,86    171,70    349,71    11,9
  2     104       143     141      ,06     36,54     99,93    162,05    11,9
  3      64       106     413     3,26       ,47      1.56     10,01    11,9
  4      65       153     796     6,60       ,27      1,26     10,75    11,9
  5      95       270    1308     9,86       ,29      1.65     13,14    11,4
  6      90       821    1770    13,25       ,23      4,24     15,02    11,4
  7     132       111     128      ,02     51,61     86,72    163,61    11,4
  8      74       160    1593    17,71       ,24      1.05     17.25    11,4
  9      58       111    1102    13,32       ,23       .87     14,08    10,7
 10      78       104     696     8,89       ,41      1.08     11,89    10,7
 11      75        89     400     4,51       ,69      1.62     12,01    10,7
 12      93        97     193      ,08     40,67     84,33    276,75    10,7
 13     114       105     116      ,01     93,71    171,72    312,32    10,9
 CYCLE COMPOSITE    BSHC    =    ,412   GRAM/KW  HR
                    BSCO+   =  1,946    GRAM/KW  HR
                    BSNO2++=  14,532    GRAM/KW  HR
             BSHC + BSNO2++=  14,944    GRAM/KW  HR
                    BSFC    =    ,272KG/KW HR

 +  CONVERTED TO WET BASIS
 ++ CONVERTED TO WET BASIS AND CORRECTED TO 10,7 MILLIGRAMS
    WATER PER <G DRY AIR
```

## TABLE C-10 13-MODE FEDERAL DIESEL EMISSION CYCLE

DDAD-8V-71TA DIESEL ENGINE IN STANDARD CONFIGURATION - 1000 HR CERT ENGINE
TEST 1 RUN 1 11-20-75 FUEL EM-246-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 480 | 4.7 | .2 | .024 | 5.92 | 5.95 | .004 |
| 2 | 1400 | 23.7 | 3.5 | .109 | 17.81 | 17.91 | .006 |
| 3 | 1400 | 320.5 | 47.0 | .227 | 18.55 | 18.78 | .012 |
| 4 | 1400 | 641.0 | 94.0 | .407 | 20.54 | 20.95 | .020 |
| 5 | 1400 | 961.4 | 140.9 | .575 | 22.25 | 22.82 | .026 |
| 6 | 1400 | 1281.9 | 187.9 | .788 | 25.38 | 26.17 | .031 |
| 7 | 480 | 4.7 | .2 | .025 | 6.24 | 6.27 | .004 |
| 8 | 2100 | 1149.0 | 252.6 | 1.017 | 35.65 | 36.67 | .029 |
| 9 | 2100 | 861.7 | 189.5 | .833 | 33.60 | 34.43 | .025 |
| 10 | 2100 | 574.5 | 126.3 | .585 | 31.02 | 31.61 | .019 |
| 11 | 2100 | 287.2 | 63.2 | .382 | 29.47 | 29.85 | .013 |
| 12 | 2100 | 21.4 | 4.7 | .210 | 27.02 | 27.24 | .008 |
| 13 | 480 | 4.7 | .2 | .030 | 6.60 | 6.63 | .005 |

| MODE | HC PPM | CO+ PPM | NO++ PPM | WEIGHTED KW | BSHC G/KW HR | BSCO+ G/KW HR | BSNO2++ G/KW HR | HUM. MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 154 | 168 | 139 | .02 | 111.66 | 242.09 | 330.18 | 3.7 |
| 2 | 172 | 243 | 81 | .28 | 25.77 | 72.66 | 39.89 | 3.7 |
| 3 | 145 | 102 | 234 | 3.76 | 1.69 | 2.36 | 8.90 | 3.7 |
| 4 | 146 | 92 | 456 | 7.52 | .95 | 1.18 | 9.68 | 3.7 |
| 5 | 154 | 324 | 721 | 11.27 | .73 | 3.04 | 11.12 | 3.7 |
| 6 | 104 | 1318 | 858 | 15.03 | .42 | 10.64 | 11.38 | 3.7 |
| 7 | 156 | 108 | 134 | .02 | 119.23 | 165.16 | 334.74 | 3.7 |
| 8 | 110 | 155 | 845 | 20.21 | .46 | 1.30 | 11.68 | 3.7 |
| 9 | 130 | 99 | 592 | 15.16 | .69 | 1.05 | 10.25 | 3.7 |
| 10 | 134 | 89 | 373 | 10.11 | .98 | 1.29 | 8.89 | 3.7 |
| 11 | 146 | 86 | 193 | 5.05 | 2.01 | 2.36 | 8.68 | 3.7 |
| 12 | 154 | 101 | 71 | .38 | 25.98 | 33.87 | 39.20 | 3.7 |
| 13 | 154 | 103 | 128 | .02 | 124.49 | 166.54 | 337.60 | 3.7 |

CYCLE COMPOSITE BSHC = 1.018 GRAM/KW HR
BSCO+ = 3.618 GRAM/KW HR
BSNO2++= 10.920 GRAM/KW HR
BSHC + BSNO2++= 11.938 GRAM/KW HR
BSFC = .281KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-11 13-MODE FEDERAL DIESEL EMISSION CYCLE

DDAD-8V-71TA DIESEL ENGINE IN STANDARD CONFIGURATION - 1000 HR CERT ENGINE
TEST 1 RUN 2 11-20-75 FUEL-EM-246-F PROJECT: 11-4016-001

| MODE | ENGINE SPEED RPM | TORQUE N X M | POWER KW | FUEL FLOW KG/MIN | AIR FLOW KG/MIN | EXHAUST FLOW KG/MIN | FUEL AIR RATIO |
|---|---|---|---|---|---|---|---|
| 1 | 480 | 2.4 | .1 | .026 | 6.15 | 6.17 | .004 |
| 2 | 1400 | 23.7 | 3.5 | .097 | 17.23 | 17.32 | .006 |
| 3 | 1400 | 313.4 | 45.9 | .235 | 19.01 | 19.24 | .012 |
| 4 | 1400 | 629.1 | 92.2 | .390 | 19.99 | 20.38 | .020 |
| 5 | 1400 | 942.4 | 138.2 | .561 | 21.78 | 22.34 | .026 |
| 6 | 1400 | 1258.2 | 184.4 | .810 | 25.24 | 26.05 | .032 |
| 7 | 480 | 4.7 | .2 | .021 | 6.22 | 6.25 | .003 |
| 8 | 2100 | 1149.0 | 252.6 | 1.039 | 36.70 | 37.74 | .028 |
| 9 | 2100 | 861.7 | 189.5 | .807 | 33.74 | 34.55 | .024 |
| 10 | 2100 | 574.5 | 126.3 | .599 | 30.60 | 31.20 | .020 |
| 11 | 2100 | 287.2 | 63.2 | .386 | 28.80 | 29.18 | .013 |
| 12 | 2100 | 21.4 | 4.7 | .206 | 26.48 | 26.69 | .008 |
| 13 | 480 | 2.4 | .1 | .026 | 6.21 | 6.23 | .004 |

| MODE | HC PPM | CO+ PPM | NO++ PPM | WEIGHTED KW | BSHC G/KW HR | BSCO+ G/KW HR | BSNO2++ G/KW HR | HUM. MILLI G/KG |
|---|---|---|---|---|---|---|---|---|
| 1 | 137 | 111 | 128 | .01 | 206.28 | 333.97 | 628.59 | 3.8 |
| 2 | 125 | 162 | 76 | .28 | 18.11 | 46.79 | 36.02 | 3.8 |
| 3 | 118 | 102 | 221 | 3.67 | 1.44 | 2.47 | 8.80 | 3.8 |
| 4 | 127 | 106 | 407 | 7.38 | .82 | 1.36 | 8.57 | 3.2 |
| 5 | 149 | 338 | 661 | 11.05 | .70 | 3.17 | 10.18 | 3.2 |
| 6 | 94 | 1529 | 868 | 14.75 | .39 | 12.52 | 11.68 | 3.2 |
| 7 | 136 | 109 | 117 | .02 | 103.59 | 164.92 | 290.56 | 3.2 |
| 8 | 98 | 130 | 840 | 20.21 | .43 | 1.13 | 11.95 | 3.2 |
| 9 | 113 | 81 | 605 | 15.16 | .60 | .86 | 10.51 | 3.2 |
| 10 | 106 | 67 | 370 | 10.11 | .76 | .96 | 8.70 | 3.2 |
| 11 | 137 | 75 | 191 | 5.05 | 1.84 | 2.02 | 8.41 | 3.8 |
| 12 | 159 | 76 | 73 | .38 | 26.29 | 25.13 | 39.60 | 3.8 |
| 13 | 112 | 82 | 125 | .01 | 170.24 | 247.42 | 621.07 | 4.4 |

CYCLE COMPOSITE BSHC = .898 GRAM/KW HR
BSCO+ = 3.683 GRAM/KW HR
BSNO2++= 10.800 GRAM/KW HR
BSHC + BSNO2++= 11.698 GRAM/KW HR
BSFC = .283KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

# APPENDIX D

# RESULTS OF FEDERAL SMOKE TEST OF FIVE HEAVY DUTY ENGINES

## TABLE D-1. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. ________ Date 2-18-75 Evaluated By KH

Model Engine 6V-71N -LSN60 1.470 Run No. 1

**Accelerations**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 14.0 | 1 | 7.5 | 1 | 7.5 |
| 2 | 19.5 | 2 | 19.5 | 2 | 15.5 |
| 3 | 12.5 | 3 | 16.5 | 3 | 15.0 |
| 4 | 8.5 | 4 | 10.0 | 4 | 13.0 |
| 5 | 6.5 | 5 | 6.0 | 5 | 4.5 |
| 6 | 3.0 | 6 | 4.0 | 6 | 3.0 |
| 7 | 2.0 | 7 | 2.5 | 7 | 2.2 |
| 8 | 2.0 | 8 | 1.7 | 8 | 1.8 |
| 9 | 1.8 | 9 | 1.5 | 9 | 2.0 |
| 10 | 1.7 | 10 | 3.2 | 10 | 2.6 |
| 11 | 2.0 | 11 | 2.2 | 11 | 2.3 |
| 12 | 2.7 | 12 | 1.7 | 12 | 2.0 |
| 13 | 2.0 | 13 | 17 | 13 | 2.0 |
| 14 | 17 | 14 | 1.5 | 14 | 1.7 |
| 15 | 1.5 | 15 | 1.5 | 15 | 2.0 |
| Total Smoke % | 81.5 | | 81.0 | | 77.1 |

Factor (a) = $\frac{239.6}{45}$ = 5.3%

**Lugging**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 1.8 | 1 | 2.0 | 1 | 2.0 |
| 2 | 1.5 | 2 | 1.8 | 2 | 2.0 |
| 3 | 1.5 | 3 | 1.8 | 3 | 2.0 |
| 4 | 15 | 4 | 1.8 | 4 | 2.0 |
| 5 | 1.6 | 5 | 1.8 | 5 | 2.0 |
| Total Smoke % | 7.9 | | 9.2 | | 10.0 |

Factor (b) = $\frac{27.1}{15}$ = 1.8%

Comments:

| | | |
|---|---|---|
| 19.5 | 19.5 | 15.5 |
| 14.0 | 16.5 | 15.0 |
| 12.5 | 10.0 | 13.0 |
| 46.0 | 46.0 | 43.5 |

$\frac{135.5}{9}$ = 15.1% "c" factor

Reproduced from best available copy.

## TABLE D-2. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. ______ Date 2-18-75 Evaluated By KH

Model Engine 6V-71N-LSN 60 1.470 Run No. 2

**Accelerations**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 11.0 | 1 | 8.0 | 1 | 6.0 |
| 2 | 18.0 | 2 | 15.0 | 2 | 15.0 |
| 3 | 11.0 | 3 | 19.5 | 3 | 18.0 |
| 4 | 7.0 | 4 | 14.5 | 4 | 12.0 |
| 5 | 5.0 | 5 | 7.0 | 5 | 9.0 |
| 6 | 3.5 | 6 | 4.5 | 6 | 5.0 |
| 7 | 2.5 | 7 | 2.5 | 7 | 4.0 |
| 8 | 2.3 | 8 | 2.0 | 8 | 2.7 |
| 9 | 2.0 | 9 | 2.0 | 9 | 2.3 |
| 10 | 2.5 | 10 | 1.8 | 10 | 2.0 |
| 11 | 3.0 | 11 | 2.7 | 11 | 2.0 |
| 12 | 2.2 | 12 | 2.0 | 12 | 2.5 |
| 13 | 2.0 | 13 | 2.0 | 13 | 3.5 |
| 14 | 2.0 | 14 | 2.0 | 14 | 2.7 |
| 15 | 1.9 | 15 | 1.7 | 15 | 2.0 |

Total Smoke % 75.7 87.2 87.7

Factor (a) = 250.6 / 45 = 5.6%

**Lugging**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 2.0 | 1 | 2.0 | 1 | 2.0 |
| 2 | 1.5 | 2 | 2.0 | 2 | 2.0 |
| 3 | 1.5 | 3 | 2.0 | 3 | 2.3 |
| 4 | 2.0 | 4 | 2.3 | 4 | 2.3 |
| 5 | 2.0 | 5 | 2.5 | 5 | 2.3 |

Total Smoke % 9.0 10.8 10.9

Factor (b) = 30.7 / 15 = 2.0%

Comments: 18.0 19.5 18.0
11.0 15.0 15.0
11.0 14.5 12.0
40.0 49.0 45.0

134.0 / 9 = 14.9% "c" factor

## TABLE D-3. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. —  Date 8-25-75  Evaluated By KH

Model Engine 6V-71 B60E 1,500  Run No. 1

**Acceleration**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 16.0 | 1 | 23.0 | 1 | 11.0 |
| 2 | 38.5 | 2 | 27.5 | 2 | 28.0 |
| 3 | 31.0 | 3 | 18.5 | 3 | 28.5 |
| 4 | 22.5 | 4 | 16.0 | 4 | 20.0 |
| 5 | 17.0 | 5 | 14.0 | 5 | 15.0 |
| 6 | 14.5 | 6 | 10.0 | 6 | 11.5 |
| 7 | 12.0 | 7 | 8.5 | 7 | 9.0 |
| 8 | 10.0 | 8 | 7.5 | 8 | 8.0 |
| 9 | 8.5 | 9 | 6.5 | 9 | 7.0 |
| 10 | 7.0 | 10 | 6.0 | 10 | 6.0 |
| 11 | 6.0 | 11 | 7.0 | 11 | 5.5 |
| 12 | 7.5 | 12 | 7.0 | 12 | 7.0 |
| 13 | 7.5 | 13 | 6.0 | 13 | 6.5 |
| 14 | 6.5 | 14 | 6.0 | 14 | 6.0 |
| 15 | 6.0 | 15 | 5.7 | 15 | 5.7 |
| Total Smoke % | 210.5 | | 169.2 | | 174.7 |

Factor (a) = $\frac{554.4}{45}$ = 12.3%

**Lugging**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 6.0 | 1 | 5.8 | 1 | 5.5 |
| 2 | 5.5 | 2 | 5.8 | 2 | 5.5 |
| 3 | 5.5 | 3 | 5.5 | 3 | 5.0 |
| 4 | 6.5 | 4 | 5.5 | 4 | 5.0 |
| 5 | 6.0 | 5 | 6.0 | 5 | 5.0 |
| Total Smoke % | 29.5 | | 28.6 | | 26.0 |

Factor (b) = $\frac{84.1}{15}$ = 5.6%

Comments: (c)

| | | |
|---|---|---|
| 38.5 | 27.5 | 28.5 |
| 31.0 | 23.0 | 28.0 |
| 22.5 | 18.5 | 20.0 |
| 92.0 | 69.0 | 76.5 |

$\frac{237.5}{9}$ = 26.4% "c" factor

## TABLE D-4. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. –    Date 8-25-75    Evaluated By KH

Model Engine 6V-71 B60E 1.500    Run No. 2

**Accelerations**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 18.0 | 1 | 12.5 | 1 | 21.5 |
| 2 | 35.0 | 2 | 23.5 | 2 | 24.0 |
| 3 | 28.0 | 3 | 28.0 | 3 | 21.5 |
| 4 | 20.0 | 4 | 21.5 | 4 | 16.0 |
| 5 | 16.0 | 5 | 17.5 | 5 | 12.5 |
| 6 | 13.5 | 6 | 13.5 | 6 | 10.0 |
| 7 | 10.5 | 7 | 11.0 | 7 | 8.5 |
| 8 | 8.5 | 8 | 10.0 | 8 | 8.0 |
| 9 | 7.0 | 9 | 9.0 | 9 | 7.0 |
| 10 | 6.5 | 10 | 7.5 | 10 | 6.0 |
| 11 | 6.0 | 11 | 6.0 | 11 | 6.0 |
| 12 | 7.5 | 12 | 6.5 | 12 | 7.0 |
| 13 | 6.5 | 13 | 7.5 | 13 | 7.0 |
| 14 | 6.5 | 14 | 6.5 | 14 | 6.5 |
| 15 | 5.5 | 15 | 6.0 | 15 | 5.5 |
| Total Smoke % | 195.0 | | 186.5 | | 167.0 |

Factor (a) = $\frac{548.5}{45}$ = 12.2 %

**Lugging**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 5.5 | 1 | 6.0 | 1 | 6.0 |
| 2 | 5.5 | 2 | 5.5 | 2 | 6.0 |
| 3 | 5.5 | 3 | 5.5 | 3 | 6.0 |
| 4 | 5.5 | 4 | 5.5 | 4 | 6.5 |
| 5 | 5.0 | 5 | 5.0 | 5 | 6.5 |
| Total Smoke % | 27.0 | | 27.5 | | 31.0 |

Factor (b) = $\frac{85.5}{15}$ = 5.7 %

Comments: (c)

| | | |
|---|---|---|
| 35.0 | 28.0 | 24.0 |
| 28.0 | 23.5 | 21.5 |
| 20.0 | 21.5 | 21.5 |
| 83.0 | 73.0 | 67.0 |

$\frac{223.0}{9}$ = 24.8 "c" factor

## TABLE D-5. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. ____________ Date 5-12-75 Evaluated By KH

Model Engine Cummins NTC-290 Low Emission Configuration Run No. 1

**Accelerations**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 28.0 | 1 | 20.5 | 1 | 22.0 |
| 2 | 40.0 | 2 | 33.5 | 2 | 30.0 |
| 3 | 27.0 | 3 | 23.0 | 3 | 20.5 |
| 4 | 20.0 | 4 | 17.0 | 4 | 15.0 |
| 5 | 16.0 | 5 | 13.5 | 5 | 12.5 |
| 6 | 13.5 | 6 | 11.0 | 6 | 11.0 |
| 7 | 12.0 | 7 | 9.5 | 7 | 9.5 |
| 8 | 11.5 | 8 | 9.0 | 8 | 8.5 |
| 9 | 11.0 | 9 | 8.0 | 9 | 8.0 |
| 10 | 9.5 | 10 | 7.5 | 10 | 7.0 |
| 11 | 8.5 | 11 | 10.5 | 11 | 10.0 |
| 12 | 14.0 | 12 | 17.5 | 12 | 15.0 |
| 13 | 12.5 | 13 | 12.5 | 13 | 10.5 |
| 14 | 9.0 | 14 | 9.0 | 14 | 8.5 |
| 15 | 7.8 | 15 | 7.5 | 15 | 7.5 |

Total Smoke % 240.3 209.5 195.5

Factor (a) = $\frac{645.3}{45}$ = 14.3 %

**Lugging**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 3.5 | 1 | 3.3 | 1 | 3.2 |
| 2 | 3.0 | 2 | 3.0 | 2 | 3.2 |
| 3 | 3.0 | 3 | 3.0 | 3 | 3.3 |
| 4 | 3.3 | 4 | 3.0 | 4 | 3.0 |
| 5 | 2.5 | 5 | 3.0 | 5 | 3.0 |

Total Smoke % 15.3 15.3 15.7

Factor (b) = $\frac{46.3}{15}$ = 3.1 %

Comments:

| | | |
|---|---|---|
| 40.0 | 33.5 | 30.0 |
| 27.0 | 23.0 | 22.0 |
| 28.0 | 20.5 | 20.5 |
| 95.0 | 77.0 | 72.5 |

$\frac{244.5}{9}$ = 27.2 % "c" factor

## TABLE D-6. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. ____________ Date 5-13-75 Evaluated By 𝑊𝐻

Model Engine Cummins NTC-290 Run No. 2
Low Emission Configuration

**Accelerations**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 16.0 | 1 | 21.0 | 1 | 15.0 |
| 2 | 44.0 | 2 | 36.0 | 2 | 38.0 |
| 3 | 38.0 | 3 | 24.0 | 3 | 28.0 |
| 4 | 24.5 | 4 | 16.0 | 4 | 19.0 |
| 5 | 20.0 | 5 | 12.5 | 5 | 14.0 |
| 6 | 15.5 | 6 | 10.0 | 6 | 11.0 |
| 7 | 14.0 | 7 | 9.5 | 7 | 9.5 |
| 8 | 12.5 | 8 | 8.0 | 8 | 9.0 |
| 9 | 11.7 | 9 | 8.5 | 9 | 8.5 |
| 10 | 10.3 | 10 | 7.5 | 10 | 7.5 |
| 11 | 9.5 | 11 | 11.0 | 11 | 9.0 |
| 12 | 10.0 | 12 | 14.5 | 12 | 12.5 |
| 13 | 15.5 | 13 | 10.0 | 13 | 9.3 |
| 14 | 12.0 | 14 | 8.0 | 14 | 7.5 |
| 15 | 9.0 | 15 | 7.0 | 15 | 6.5 |

Total Smoke % 262.5 203.5 204.3

Factor (a) = 670.3 / 45 = 14.9%

**Lugging**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 3.5 | 1 | 2.7 | 1 | 2.7 |
| 2 | 3.0 | 2 | 2.7 | 2 | 2.5 |
| 3 | 3.0 | 3 | 2.7 | 3 | 2.5 |
| 4 | 3.0 | 4 | 2.3 | 4 | 2.5 |
| 5 | 2.8 | 5 | 2.3 | 5 | 2.5 |

Total Smoke % 15.3 12.7 12.7

Factor (b) = 40.7 / 15 = 2.7%

Comments:

| | | |
|---|---|---|
| 44.0 | 36.0 | 38.0 |
| 38.0 | 24.0 | 28.0 |
| 24.5 | 21.0 | 19.0 |
| 106.5 | 81.0 | 85.0 |

$\frac{272.5}{9}$ = 30.3% "C" factor

## TABLE D-7. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. ________ Date 6-25-75 Evaluated By KH

Model Engine Cummins NTC-290 Run No. 1

Current Emission Configuration

**Accelerations**

| First Sequence |  | Second Sequence |  | Third Sequence |  |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 17.0 | 1 | 5.0 | 1 | 5.0 |
| 2 | 34.0 | 2 | 17.5 | 2 | 19.0 |
| 3 | 31.0 | 3 | 23.0 | 3 | 25.0 |
| 4 | 26.0 | 4 | 21.0 | 4 | 23.0 |
| 5 | 21.5 | 5 | 18.5 | 5 | 17.5 |
| 6 | 18.5 | 6 | 14.0 | 6 | 15.5 |
| 7 | 14.0 | 7 | 11.5 | 7 | 11.5 |
| 8 | 11.0 | 8 | 8.5 | 8 | 8.5 |
| 9 | 8.5 | 9 | 6.0 | 9 | 6.0 |
| 10 | 11.0 | 10 | 5.5 | 10 | 5.5 |
| 11 | 23.0 | 11 | 16.0 | 11 | 18.0 |
| 12 | 16.0 | 12 | 23.0 | 12 | 23.5 |
| 13 | 10.0 | 13 | 12.5 | 13 | 13.0 |
| 14 | 7.5 | 14 | 8.0 | 14 | 8.0 |
| 15 | 6.0 | 15 | 5.5 | 15 | 5.0 |

Total Smoke % 255.0 195.5 204.0

Factor (a) = $\frac{654.5}{45}$ = 14.5 %

**Lugging**

| First Sequence |  | Second Sequence |  | Third Sequence |  |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 2.3 | 1 | 3.5 | 1 | 2.5 |
| 2 | 2.5 | 2 | 3.5 | 2 | 2.5 |
| 3 | 2.5 | 3 | 3.5 | 3 | 2.5 |
| 4 | 2.5 | 4 | 3.5 | 4 | 2.3 |
| 5 | 2.5 | 5 | 3.0 | 5 | 2.3 |

Total Smoke % 12.8 17.0 12.1

Factor (b) = $\frac{41.9}{15}$ = 2.8 %

Comments:

|  |  |  |
|---|---|---|
| 34.0 | 23.0 | 25.0 |
| 31.0 | 21.0 | 23.0 |
| 26.0 | 18.5 | 19.0 |
| 91.0 | 62.5 | 67.0 |

$\frac{220.5}{9}$ = 24.5 % "C" Factor

## TABLE D-8. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. ____________ Date 6-25-75 Evaluated By KH

Model Engine Cummins NTC 290 Run No. 2
Current Emission Configuration

**Accelerations**

| First Sequence |  | Second Sequence |  | Third Sequence |  |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 10.0 | 1 | 12.0 | 1 | 15.0 |
| 2 | 28.5 | 2 | 25.0 | 2 | 23.0 |
| 3 | 34.5 | 3 | 22.0 | 3 | 22.5 |
| 4 | 25.0 | 4 | 21.0 | 4 | 20.0 |
| 5 | 20.0 | 5 | 17.0 | 5 | 17.5 |
| 6 | 18.0 | 6 | 13.0 | 6 | 14.5 |
| 7 | 14.5 | 7 | 10.0 | 7 | 11.0 |
| 8 | 10.0 | 8 | 8.0 | 8 | 8.0 |
| 9 | 8.0 | 9 | 6.0 | 9 | 6.0 |
| 10 | 7.0 | 10 | 5.0 | 10 | 5.0 |
| 11 | 16.0 | 11 | 8.0 | 11 | 15.5 |
| 12 | 21.0 | 12 | 21.0 | 12 | 21.0 |
| 13 | 13.0 | 13 | 17.0 | 13 | 12.5 |
| 14 | 8.5 | 14 | 9.5 | 14 | 8.0 |
| 15 | 6.0 | 15 | 6.5 | 15 | 5.5 |

Total Smoke % 240.0 201.0 205.0

Factor (a) = $\frac{646.0}{45}$ = 14.4 %

**Lugging**

| First Sequence |  | Second Sequence |  | Third Sequence |  |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 2.0 | 1 | 2.5 | 1 | 3.0 |
| 2 | 2.0 | 2 | 2.5 | 2 | 3.0 |
| 3 | 2.0 | 3 | 2.5 | 3 | 3.0 |
| 4 | 2.0 | 4 | 2.5 | 4 | 3.0 |
| 5 | 2.0 | 5 | 2.0 | 5 | 3.0 |

Total Smoke % 10.0 11.8 15.0

Factor (b) = $\frac{36.8}{15}$ = 2.5 %

Comments:

|  |  |  |
|---|---|---|
| 34.5 | 25.0 | 23.0 |
| 28.5 | 22.0 | 22.5 |
| 25.0 | 21.0 | 21.0 |
| 88.0 | 68.0 | 66.5 |

$\frac{222.5}{9}$ = 24.7 % "C" factor

## TABLE D-9. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. ____________ Date 10-27-75 Evaluated By KH

Model Engine DDAD 8V-71T Run No. 1

**Accelerations**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 10.0 | 1 | 16.0 | 1 | 18.0 |
| 2 | 20.0 | 2 | 33.0 | 2 | 34.0 |
| 3 | 18.5 | 3 | 30.5 | 3 | 24.5 |
| 4 | 16.5 | 4 | 26.5 | 4 | 23.0 |
| 5 | 15.0 | 5 | 24.5 | 5 | 19.0 |
| 6 | 13.0 | 6 | 22.0 | 6 | 19.5 |
| 7 | 12.0 | 7 | 18.0 | 7 | 16.0 |
| 8 | 11.5 | 8 | 15.0 | 8 | 13.5 |
| 9 | 11.0 | 9 | 11.5 | 9 | 11.5 |
| 10 | 9.0 | 10 | 10.0 | 10 | 9.0 |
| 11 | 8.0 | 11 | 8.5 | 11 | 7.0 |
| 12 | 7.0 | 12 | 4.0 | 12 | 7.0 |
| 13 | 6.5 | 13 | 4.5 | 13 | 6.0 |
| 14 | 4.5 | 14 | 4.5 | 14 | 10.0 |
| 15 | 4.0 | 15 | 4.5 | 15 | 8.5 |

Total Smoke % 166.5 233.0 231.5

Factor (a) = $\frac{631.0}{45}$ = 14.0 %

**Lugging**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 5.5 | 1 | 6.0 | 1 | 5.5 |
| 2 | 6.5 | 2 | 6.0 | 2 | 5.5 |
| 3 | 7.5 | 3 | 6.0 | 3 | 6.0 |
| 4 | 8.0 | 4 | 7.0 | 4 | 6.5 |
| 5 | 8.0 | 5 | 7.5 | 5 | 6.5 |

Total Smoke % 35.5 32.5 30.0

Factor (b) = $\frac{98}{15}$ = 6.5 %

Comments:

| | | | | | |
|---|---|---|---|---|---|
| 1 | 20.0 | 1 | 33.0 | 1 | 34.0 |
| 2 | 18.5 | 2 | 30.5 | 2 | 24.5 |
| 3 | 16.5 | 3 | 26.5 | 3 | 23.0 |
| | 55.0 | | 90.0 | | 86.5 |

231.5
= 25.7% = factor

## TABLE D-10. SMOKEMETER OPACITY READINGS FROM FEDERAL SMOKE TEST

Vehicle No. ________ Date 10-29-75 Evaluated By KH

Model Engine DDAD 8V-71T Run No. 2

**Accelerations**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 8.0 | 1 | 20.0 | 1 | 18.5 |
| 2 | 17.0 | 2 | 24.0 | 2 | 40.0 |
| 3 | 15.0 | 3 | 22.0 | 3 | 37.0 |
| 4 | 13.0 | 4 | 20.0 | 4 | 32.0 |
| 5 | 11.0 | 5 | 17.0 | 5 | 32.0 |
| 6 | 11.0 | 6 | 17.0 | 6 | 30.5 |
| 7 | 10.0 | 7 | [illegible] | 7 | [illegible] |
| 8 | 10.0 | 8 | 13.0 | 8 | 21.0 |
| 9 | 9.0 | 9 | 10.0 | 9 | 16.5 |
| 10 | 7.5 | 10 | 8.5 | 10 | 13.0 |
| 11 | 6.5 | 11 | 5.0 | 11 | 9.0 |
| 12 | 5.5 | 12 | 5.0 | 12 | 4.0 |
| 13 | 5.0 | 13 | 5.0 | 13 | 4.5 |
| 14 | 4.0 | 14 | 5.0 | 14 | 4.5 |
| 15 | 4.0 | 15 | 5.0 | 15 | 4.5 |

Total Smoke % 136.5 192.5 214.0

Factor (a) = $\frac{623.0}{45}$ = 13.8 %

**Lugging**

| First Sequence | | Second Sequence | | Third Sequence | |
|---|---|---|---|---|---|
| Interval No. | Smoke % | Interval No. | Smoke % | Interval No. | Smoke % |
| 1 | 6.0 | 1 | 6.5 | 1 | 6.0 |
| 2 | 6.0 | 2 | 7.5 | 2 | 6.0 |
| 3 | 6.0 | 3 | 7.5 | 3 | 6.5 |
| 4 | 6.5 | 4 | 8.0 | 4 | 7.5 |
| 5 | 7.0 | 5 | 7.5 | 5 | 7.5 |

Total Smoke % 31.5 37.0 33.5

Factor (b) = $\frac{102.0}{15}$ = 6.8 %

Comments:

| | | |
|---|---|---|
| 17.0 | 24.0 | 40.0 |
| 15.0 | 22.0 | 37.0 |
| 13.0 | 20.0 | 32.0 |
| 35.0 | 66.0 | 109.0 |

$\frac{210.0}{9}$ = 23.3 % [illegible] [illegible]

# APPENDIX E

# ODOR RATING BY EPA Q/I METHOD OF FIVE HEAVY DUTY ENGINES

## TABLE E-1. COMPARISON OF ODOR RATINGS
### Detroit Diesel 6V-71 Engine

| Condition | Date | Conf. | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|---|
| 900 rpm<br>2% load | 8/19/75 | LSN | 2.8 | 1.0 | 1.0 | 0.7 | 0.4 |
| | 8/21/75 | LSN | 2.9 | 1.0 | 0.9 | 0.6 | 0.5 |
| | Average | | 2.9 | 1.0 | 1.0 | 0.7 | 0.5 |
| | 8/26/75 | B60E | 3.2 | 1.0 | 1.0 | 0.8 | 0.5 |
| | 8/28/75 | B60E | 3.0 | 1.0 | 0.9 | 0.7 | 0.6 |
| | Average | | 3.1 | 1.0 | 1.0 | 0.8 | 0.6 |
| 900 rpm<br>50% load | 8/19/75 | LSN | 2.5 | 1.0 | 0.9 | 0.5 | 0.3 |
| | 8/21/75 | LSN | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| | Average | | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| | 8/26/75 | B60E | 2.2 | 1.0 | 0.9 | 0.5 | 0.3 |
| | 8/28/75 | B60E | 2.4 | 1.0 | 0.9 | 0.5 | 0.3 |
| | Average | | 2.3 | 1.0 | 0.9 | 0.5 | 0.3 |
| 900 rpm<br>100% load | 8/19/75 | LSN | 4.7 | 1.7 | 1.0 | 0.8 | 1.2 |
| | 8/21/75 | LSN | 4.6 | 1.5 | 1.0 | 0.9 | 1.1 |
| | Average | | 4.7 | 1.6 | 1.0 | 0.9 | 1.2 |
| | 8/26/75 | B60E | 3.4 | 1.0 | 1.0 | 0.6 | 0.9 |
| | 8/28/75 | B60E | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| | Average | | 3.4 | 1.0 | 1.0 | 0.7 | 0.9 |
| 1500 rpm<br>2% load | 8/19/75 | LSN | 2.7 | 1.0 | 0.9 | 0.7 | 0.4 |
| | 8/21/75 | LSN | 3.0 | 1.0 | 0.9 | 0.8 | 0.5 |
| | Average | | 2.9 | 1.0 | 0.9 | 0.8 | 0.5 |
| | 8/26/75 | B60E | 3.5 | 1.0 | 1.0 | 0.8 | 0.8 |
| | 8/28/75 | B60E | 3.2 | 1.0 | 0.9 | 0.8 | 0.6 |
| | Average | | 3.4 | 1.0 | 1.0 | 0.8 | 0.7 |
| 1500 rpm<br>50% load | 8/19/75 | LSN | 2.8 | 1.0 | 1.0 | 0.7 | 0.4 |
| | 8/21/75 | LSN | 2.6 | 1.0 | 0.9 | 0.5 | 0.6 |
| | Average | | 2.7 | 1.0 | 1.0 | 0.6 | 0.5 |
| | 8/26/75 | B60E | 2.3 | 1.0 | 0.9 | 0.4 | 0.4 |
| | 8/28/75 | B60E | 2.7 | 1.0 | 1.0 | 0.6 | 0.5 |
| | Average | | 2.5 | 1.0 | 1.0 | 0.5 | 0.5 |
| 1500 rpm<br>100% load | 8/19/75 | LSN | 4.2 | 1.2 | 1.0 | 0.9 | 1.0 |
| | 8/21/75 | LSN | 3.9 | 1.1 | 1.0 | 1.0 | 0.8 |
| | Average | | 4.1 | 1.2 | 1.0 | 1.0 | 0.9 |
| | 8/26/75 | B60E | 3.9 | 1.0 | 1.0 | 0.8 | 1.0 |
| | 8/28/75 | B60E | 3.4 | 1.1 | 1.0 | 0.7 | 0.8 |
| | Average | | 3.7 | 1.1 | 1.0 | 0.8 | 0.9 |

TABLE E-1 (Cont'd.) COMPARISON OF ODOR RATINGS
Detroit Diesel 6V-71 Engine

| | | | "D" | "B" | "O" | "A" | "P" |
|---|---|---|---|---|---|---|---|
| Condition | Date | Conf. | Composite | Burnt | Oily | Aromatic | Pungent |
| Idle | 8/19/75 | LSN | 2.8 | 1.0 | 0.9 | 0.8 | 0.5 |
| | 8/21/75 | LSN | 3.1 | 1.0 | 0.9 | 0.8 | 0.6 |
| | Average | | 3.0 | 1.0 | 0.9 | 0.8 | 0.6 |
| | 8/26/75 | B60E | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| | 8/28/75 | B60E | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| | Average | | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| Idle-Acceleration | 8/19/75 | LSN | 5.1 | 1.8 | 1.1 | 1.0 | 1.1 |
| | 8/21/75 | LSN | 5.1 | 1.8 | 1.1 | 1.0 | 1.0 |
| | Average | | 5.1 | 1.8 | 1.1 | 1.0 | 1.1 |
| | 8/26/75 | B60E | 4.0 | 1.2 | 1.0 | 0.9 | 1.0 |
| | 8/28/75 | B60E | 3.6 | 1.1 | 1.1 | 0.8 | 0.9 |
| | Average | | 3.8 | 1.2 | 1.1 | 0.9 | 1.0 |
| Acceleration | 8/19/75 | LSN | 4.8 | 1.6 | 1.1 | 1.0 | 1.0 |
| | 8/21/75 | LSN | 4.4 | 1.4 | 1.0 | 1.0 | 1.0 |
| | Average | | 4.6 | 1.5 | 1.1 | 1.0 | 1.0 |
| | 8/26/75 | B60E | 3.8 | 1.2 | 1.0 | 0.8 | 1.0 |
| | 8/28/75 | B60E | 3.4 | 1.0 | 1.0 | 0.7 | 0.9 |
| | Average | | 3.6 | 1.1 | 1.0 | 0.8 | 1.0 |
| Deceleration | 8/19/75 | LSN | 3.2 | 1.0 | 1.0 | 0.9 | 0.6 |
| | 8/21/75 | LSN | 3.2 | 1.0 | 1.0 | 0.8 | 0.7 |
| | Average | | 3.2 | 1.0 | 1.0 | 0.9 | 0.7 |
| | 8/26/75 | B60E | 2.8 | 1.0 | 0.9 | 0.7 | 0.4 |
| | 8/28/75 | B60E | 2.9 | 1.0 | 0.9 | 0.7 | 0.5 |
| | Average | | 2.9 | 1.0 | 0.9 | 0.7 | 0.5 |

## TABLE E-2. ODOR EVALUATION SUMMARY

Engine: Detroit Diesel 6V-71
Date: August 19, 1975

Injectors: LSN 60
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 3. | 900 rpm | 2.8 | 1.0 | 1.0 | 0.8 | 0.5 |
| 13. | 2% load | 2.3 | 1.0 | 0.9 | 0.3 | 0.4 |
| 17. | | 3.2 | 1.0 | 1.0 | 0.9 | 0.4 |
| | | 2.8 | 1.0 | 1.0 | 0.7 | 0.4 |
| 1. | 900 rpm | 2.9 | 1.0 | 1.0 | 0.8 | 0.4 |
| 6. | 50% load | 2.2 | 1.0 | 1.0 | 0.1 | 0.3 |
| 11. | | 2.3 | 0.9 | 0.8 | 0.6 | 0.2 |
| | | 2.5 | 1.0 | 0.9 | 0.5 | 0.3 |
| 8. | 900 rpm | 5.0 | 1.7 | 1.0 | 0.9 | 1.3 |
| 16. | 100% load | 4.6 | 1.7 | 1.0 | 0.8 | 1.1 |
| 20. | | 4.6 | 1.7 | 1.0 | 0.8 | 1.1 |
| | | 4.7 | 1.7 | 1.0 | 0.8 | 1.2 |
| 10. | 1500 rpm | 2.9 | 1.0 | 1.0 | 0.7 | 0.6 |
| 15. | 2% load | 2.6 | 1.0 | 0.9 | 0.6 | 0.2 |
| 21. | | 2.7 | 1.0 | 0.8 | 0.8 | 0.3 |
| | | 2.7 | 1.0 | 0.9 | 0.7 | 0.4 |
| 4. | 1500 rpm | 3.0 | 1.0 | 1.0 | 0.8 | 0.3 |
| 9. | 50% load | 2.7 | 0.9 | 0.9 | 0.4 | 0.6 |
| 18. | | 2.7 | 1.0 | 1.0 | 0.8 | 0.2 |
| | | 2.8 | 1.0 | 1.0 | 0.7 | 0.4 |
| 2. | 1500 rpm | 4.6 | 1.6 | 1.0 | 0.8 | 1.0 |
| 5. | 100% load | 4.1 | 1.0 | 1.0 | 0.9 | 0.9 |
| 14. | | 4.0 | 1.0 | 1.0 | 0.9 | 1.0 |
| | | 4.2 | 1.2 | 1.0 | 0.9 | 1.0 |
| 7. | Idle | 2.7 | 1.0 | 0.8 | 0.9 | 0.3 |
| 12. | | 2.9 | 1.0 | 0.9 | 0.7 | 0.6 |
| 19. | | 2.8 | 1.1 | 0.9 | 0.7 | 0.6 |
| | | 2.8 | 1.0 | 0.9 | 0.8 | 0.5 |
| 22. | Idle-Acceleration | 5.0 | 1.8 | 1.0 | 1.0 | 1.1 |
| 27. | | 5.1 | 1.9 | 1.1 | 1.0 | 1.1 |
| 29. | | 4.9 | 1.4 | 1.0 | 1.0 | 1.1 |
| 31. | | 5.4 | 1.9 | 1.4 | 1.0 | 1.1 |
| | | 5.1 | 1.8 | 1.1 | 1.0 | 1.1 |
| 23. | Acceleration | 4.9 | 1.8 | 1.1 | 0.9 | 1.1 |
| 26. | | 5.1 | 1.7 | 1.1 | 0.9 | 1.1 |
| 28. | | 4.6 | 1.4 | 1.1 | 1.0 | 0.9 |
| 32. | | 4.5 | 1.4 | 1.0 | 1.0 | 0.9 |
| | | 4.8 | 1.6 | 1.1 | 1.0 | 1.0 |
| 24. | Deceleration | 3.1 | 1.0 | 1.0 | 0.8 | 0.7 |
| 25. | | 2.9 | 1.0 | 1.0 | 0.8 | 0.6 |
| 30. | | 3.0 | 1.1 | 1.0 | 1.0 | 0.3 |
| 33. | | 3.8 | 1.0 | 1.0 | 1.1 | 0.6 |
| | | 3.2 | 1.0 | 1.0 | 0.9 | 0.6 |

## TABLE E-3. ODOR EVALUATION SUMMARY

Engine: Detroit Diesel 6V-71
Date: August 21, 1975

Injectors: LSN 60
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 5. | 900 rpm 2% load | 3.1 | 1.0 | 0.9 | 0.9 | 0.7 |
| 12. | | 2.6 | 1.0 | 0.9 | 0.4 | 0.4 |
| 20. | | 3.0 | 1.0 | 1.0 | 0.6 | 0.4 |
| | | 2.9 | 1.0 | 0.9 | 0.6 | 0.5 |
| 4. | 900 rpm 50% load | 2.6 | 1.0 | 0.9 | 0.6 | 0.4 |
| 14. | | 2.1 | 1.0 | 0.7 | 0.4 | 0.3 |
| 21. | | 2.9 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| 1. | 900 rpm 100% load | 4.0 | 1.1 | 1.0 | 0.7 | 1.0 |
| 8. | | 4.9 | 1.7 | 1.1 | 0.9 | 1.1 |
| 18. | | 5.0 | 1.7 | 1.0 | 1.0 | 1.1 |
| | | 4.6 | 1.5 | 1.0 | 0.9 | 1.1 |
| 6. | 1500 rpm 2% load | 3.3 | 1.0 | 0.9 | 0.9 | 0.6 |
| 13. | | 2.7 | 1.0 | 0.9 | 0.6 | 0.4 |
| 19. | | 3.1 | 1.0 | 1.0 | 0.9 | 0.6 |
| | | 3.0 | 1.0 | 0.9 | 0.8 | 0.5 |
| 7. | 1500 rpm 50% load | 3.0 | 1.0 | 1.0 | 0.6 | 0.7 |
| 10. | | 2.0 | 1.0 | 0.7 | 0.6 | 0.3 |
| 15. | | 2.9 | 1.0 | 1.0 | 0.3 | 0.7 |
| | | 2.6 | 1.0 | 0.9 | 0.5 | 0.6 |
| 2. | 1500 rpm 100% load | 3.6 | 1.0 | 0.9 | 1.0 | 0.9 |
| 9. | | 3.3 | 1.0 | 1.0 | 0.9 | 0.6 |
| 17. | | 4.7 | 1.4 | 1.0 | 1.0 | 1.0 |
| | | 3.9 | 1.1 | 1.0 | 1.0 | 0.8 |
| 3. | Idle | 2.9 | 1.0 | 0.9 | 0.9 | 0.3 |
| 11. | | 3.0 | 1.0 | 0.9 | 0.9 | 0.4 |
| 16. | | 3.3 | 1.0 | 1.0 | 0.6 | 1.0 |
| | | 3.1 | 1.0 | 0.9 | 0.8 | 0.6 |
| 24. | Idle-Acceleration | 4.9 | 1.9 | 1.0 | 1.0 | 1.0 |
| 25. | | 5.2 | 1.9 | 1.0 | 1.1 | 1.0 |
| 29. | | 5.4 | 2.0 | 1.1 | 1.0 | 1.1 |
| 32. | | 4.7 | 1.3 | 1.1 | 1.0 | 1.0 |
| | | 5.1 | 1.8 | 1.1 | 1.0 | 1.0 |
| 22. | Acceleration | 4.6 | 1.6 | 1.0 | 0.9 | 1.0 |
| 27. | | 4.4 | 1.4 | 1.0 | 0.9 | 0.9 |
| 30. | | 4.1 | 1.3 | 1.0 | 1.0 | 1.0 |
| 33. | | 4.4 | 1.4 | 1.0 | 1.0 | 1.0 |
| | | 4.4 | 1.4 | 1.0 | 1.0 | 1.0 |
| 23. | Deceleration | 3.0 | 1.0 | 1.0 | 0.9 | 0.4 |
| 26. | | 3.6 | 1.1 | 1.0 | 0.7 | 0.9 |
| 28. | | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |
| 31. | | 3.3 | 1.0 | 1.0 | 0.9 | 0.7 |
| | | 3.2 | 1.0 | 1.0 | 0.8 | 0.7 |

## TABLE E-4. ODOR EVALUATION SUMMARY

Engine: Detroit Diesel 6V-71
Date: August 26, 1975

Injectors: B60E
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 2. | 900 rpm | 3.4 | 1.0 | 1.0 | 0.9 | 0.5 |
| 7. | 2% load | 3.0 | 1.0 | 0.9 | 0.6 | 0.5 |
| 12. | | 3.1 | 1.0 | 1.0 | 0.8 | 0.5 |
| | | 3.2 | 1.0 | 1.0 | 0.8 | 0.5 |
| 8. | 900 rpm | 2.4 | 1.0 | 1.0 | 0.6 | 0.3 |
| 17. | 50% load | 2.4 | 1.0 | 0.9 | 0.5 | 0.3 |
| 20. | | 1.9 | 1.0 | 0.7 | 0.3 | 0.2 |
| | | 2.2 | 1.0 | 0.9 | 0.5 | 0.3 |
| 14. | 900 rpm | 3.9 | 1.0 | 1.0 | 0.8 | 1.0 |
| 16. | 100% load | 2.8 | 1.0 | 1.0 | 0.5 | 0.6 |
| 18. | | 3.4 | 1.0 | 1.0 | 0.5 | 1.0 |
| | | 3.4 | 1.0 | 1.0 | 0.6 | 0.9 |
| 4. | 1500 rpm | 3.2 | 1.0 | 0.9 | 0.9 | 0.7 |
| 11. | 2% load | 3.3 | 1.1 | 1.0 | 0.5 | 0.8 |
| 19. | | 4.0 | 1.0 | 1.0 | 0.9 | 1.0 |
| | | 3.5 | 1.0 | 1.0 | 0.8 | 0.8 |
| 3. | 1500 rpm | 2.5 | 1.0 | 1.0 | 0.5 | 0.5 |
| 10. | 50% load | 2.2 | 1.0 | 0.8 | 0.5 | 0.2 |
| 15. | | 2.2 | 1.0 | 0.8 | 0.3 | 0.4 |
| | | 2.3 | 1.0 | 0.9 | 0.4 | 0.4 |
| 1. | 1500 rpm | 4.1 | 1.0 | 1.0 | 1.0 | 1.0 |
| 5. | 100% load | 3.7 | 1.1 | 0.9 | 0.5 | 1.1 |
| 9. | | 3.8 | 1.0 | 1.0 | 1.0 | 0.8 |
| | | 3.9 | 1.0 | 1.0 | 0.8 | 1.0 |
| 6. | Idle | 3.1 | 1.0 | 1.0 | 0.4 | 0.6 |
| 13. | | 2.8 | 1.0 | 0.8 | 0.7 | 0.6 |
| 21. | | 2.5 | 1.0 | 1.0 | 0.6 | 0.2 |
| | | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| 24. | Idle-Acceleration | 4.2 | 1.4 | 1.0 | 0.9 | 0.9 |
| 26. | | 3.7 | 1.0 | 1.0 | 0.9 | 0.9 |
| 30. | | 4.0 | 1.3 | 1.0 | 0.8 | 1.0 |
| 31. | | 4.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | 4.0 | 1.2 | 1.0 | 0.9 | 1.0 |
| 23. | Acceleration | 4.0 | 1.2 | 1.1 | 0.8 | 1.0 |
| 25. | | 3.9 | 1.1 | 1.0 | 0.6 | 1.1 |
| 29. | | 4.4 | 1.4 | 1.1 | 1.0 | 1.1 |
| 32. | | 2.9 | 1.0 | 0.9 | 0.9 | 0.6 |
| | | 3.8 | 1.2 | 1.0 | 0.8 | 1.0 |
| 22. | Deceleration | 2.3 | 1.0 | 0.8 | 0.7 | 0.2 |
| 27. | | 3.5 | 1.0 | 1.0 | 1.0 | 0.5 |
| 28. | | 2.8 | 1.0 | 0.9 | 0.6 | 0.6 |
| 33. | | 2.4 | 1.0 | 1.0 | 0.5 | 0.3 |
| | | 2.8 | 1.0 | 0.9 | 0.7 | 0.4 |

## TABLE E-5. ODOR EVALUATION SUMMARY

Engine: Detroit Diesel 6V-71
Date: August 28, 1975

Injectors: B60E
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 1. | 900 rpm 2% load | 3.0 | 1.0 | 0.8 | 0.8 | 0.5 |
| 6. | | 3.5 | 1.0 | 1.0 | 0.7 | 0.8 |
| 13. | | 2.4 | 1.0 | 0.9 | 0.6 | 0.4 |
| | | 3.0 | 1.0 | 0.9 | 0.7 | 0.6 |
| 3. | 900 rpm 50% load | 2.6 | 1.0 | 0.9 | 0.6 | 0.4 |
| 11. | | 2.1 | 1.0 | 0.9 | 0.4 | 0.2 |
| 19. | | 2.4 | 1.0 | 0.9 | 0.5 | 0.2 |
| | | 2.4 | 1.0 | 0.9 | 0.5 | 0.3 |
| 9. | 900 rpm 100% load | 3.1 | 1.0 | 0.9 | 0.8 | 0.7 |
| 15. | | 3.9 | 1.0 | 1.0 | 0.9 | 1.1 |
| 17. | | 2.9 | 1.0 | 1.0 | 0.6 | 0.5 |
| | | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| 2. | 1500 rpm 2% load | 3.7 | 1.0 | 1.1 | 0.9 | 0.7 |
| 10. | | 2.7 | 1.0 | 0.7 | 0.6 | 0.6 |
| 18. | | 3.1 | 1.0 | 0.9 | 0.9 | 0.5 |
| | | 3.2 | 1.0 | 0.9 | 0.8 | 0.6 |
| 7. | 1500 rpm 50% load | 2.6 | 1.0 | 1.0 | 0.6 | 0.4 |
| 14. | | 3.0 | 1.0 | 1.0 | 0.6 | 0.6 |
| 21. | | 2.6 | 1.0 | 0.9 | 0.5 | 0.4 |
| | | 2.7 | 1.0 | 1.0 | 0.6 | 0.5 |
| 4. | 1500 rpm 100% load | 3.8 | 1.1 | 1.0 | 0.9 | 0.9 |
| 8. | | 3.7 | 1.1 | 1.0 | 0.7 | 0.8 |
| 16. | | 2.8 | 1.0 | 0.9 | 0.5 | 0.6 |
| | | 3.4 | 1.1 | 1.0 | 0.7 | 0.8 |
| 5. | Idle | 3.4 | 1.0 | 0.9 | 0.8 | 0.7 |
| 11. | | 2.1 | 1.0 | 0.9 | 0.4 | 0.2 |
| 20. | | 2.9 | 1.0 | 0.9 | 0.6 | 0.5 |
| | | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| 22. | Idle-Acceleration | 4.0 | 1.1 | 1.1 | 0.9 | 1.0 |
| 27. | | 3.9 | 1.2 | 1.1 | 0.8 | 1.0 |
| 29. | | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| 32. | | 3.3 | 1.1 | 1.0 | 0.7 | 0.8 |
| | | 3.6 | 1.1 | 1.1 | 0.8 | 0.9 |
| 23. | Acceleration | 3.1 | 1.0 | 1.0 | 0.8 | 0.7 |
| 26. | | 3.7 | 1.1 | 1.0 | 0.6 | 1.0 |
| 28. | | 3.3 | 1.0 | 1.0 | 0.6 | 0.9 |
| 31. | | 3.6 | 1.0 | 1.0 | 0.7 | 1.0 |
| | | 3.4 | 1.0 | 1.0 | 0.7 | 0.9 |
| 24. | Deceleration | 2.3 | 1.0 | 0.9 | 0.5 | 0.1 |
| 25. | | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| 30. | | 3.2 | 1.0 | 0.9 | 0.7 | 0.7 |
| 33. | | 3.2 | 1.0 | 1.0 | 0.9 | 0.6 |
| | | 2.9 | 1.0 | 0.9 | 0.7 | 0.5 |

## TABLE E-6. COMPARISON OF ODOR RATINGS
### Cummins NTC-290

| Condition | Date | Conf.* | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|---|
| 1400 rpm 2% load | 8/5/75 | C | 2.3 | 1.0 | 0.9 | 0.3 | 0.4 |
| | 8/7/75 | C | 2.4 | 0.9 | 0.9 | 0.6 | 0.2 |
| | Average | | 2.4 | 1.0 | 0.9 | 0.5 | 0.3 |
| | 8/12/75 | L | 2.4 | 1.0 | 0.9 | 0.4 | 0.3 |
| | 8/14/75 | L | 2.4 | 1.0 | 0.8 | 0.5 | 0.4 |
| | Average | | 2.4 | 1.0 | 0.9 | 0.5 | 0.4 |
| 1400 rpm 50% load | 8/5/75 | C | 2.5 | 1.0 | 1.0 | 0.5 | 0.3 |
| | 8/7/75 | C | 2.1 | 0.9 | 0.7 | 0.4 | 0.2 |
| | Average | | 2.3 | 1.0 | 0.9 | 0.5 | 0.3 |
| | 8/12/75 | L | 2.7 | 1.0 | 0.9 | 0.5 | 0.5 |
| | 8/14/75 | L | 2.5 | 0.9 | 0.9 | 0.6 | 0.3 |
| | Average | | 2.6 | 1.0 | 0.9 | 0.6 | 0.4 |
| 1400 rpm 100% load | 8/5/75 | C | 2.1 | 1.0 | 0.9 | 0.4 | 0.3 |
| | 8/7/75 | C | 1.9 | 0.9 | 0.8 | 0.2 | 0.2 |
| | Average | | 2.0 | 1.0 | 0.9 | 0.3 | 0.3 |
| | 8/12/75 | L | 2.3 | 0.9 | 0.7 | 0.7 | 0.3 |
| | 8/14/75 | L | 2.3 | 1.0 | 0.8 | 0.4 | 0.2 |
| | Average | | 2.3 | 1.0 | 0.8 | 0.6 | 0.3 |
| 2100 rpm 2% load | 8/5/75 | C | 2.3 | 1.0 | 0.6 | 0.6 | 0.3 |
| | 8/7/75 | C | 2.3 | 0.9 | 0.8 | 0.4 | 0.3 |
| | Average | | 2.3 | 1.0 | 0.7 | 0.5 | 0.3 |
| | 8/12/75 | L | 2.4 | 1.0 | 0.9 | 0.4 | 0.3 |
| | 8/14/75 | L | 2.0 | 1.0 | 0.7 | 0.3 | 0.2 |
| | Average | | 2.2 | 1.0 | 0.8 | 0.4 | 0.3 |
| 2100 rpm 50% load | 8/5/75 | C | 2.4 | 1.0 | 0.8 | 0.5 | 0.3 |
| | 8/7/75 | C | 2.6 | 0.9 | 0.9 | 0.5 | 0.3 |
| | Average | | 2.5 | 1.0 | 0.9 | 0.5 | 0.3 |
| | 8/12/75 | L | 3.0 | 1.0 | 1.0 | 0.7 | 0.5 |
| | 8/14/75 | L | 3.0 | 1.0 | 1.0 | 0.7 | 0.5 |
| | Average | | 3.0 | 1.0 | 1.0 | 0.7 | 0.5 |
| 2100 rpm 100% load | 8/5/75 | C | 3.1 | 1.0 | 0.9 | 0.6 | 0.6 |
| | 8/7/75 | C | 2.8 | 1.0 | 1.0 | 0.5 | 0.6 |
| | Average | | 3.0 | 1.0 | 1.0 | 0.6 | 0.6 |
| | 8/12/75 | L | 1.9 | 0.9 | 0.7 | 0.5 | 0.2 |
| | 8/14/75 | L | 2.3 | 1.0 | 1.0 | 0.4 | 0.2 |
| | Average | | 2.1 | 1.0 | 0.9 | 0.5 | 0.2 |

---

*C - "Current Emission Configuration"
L - "Low Emission Configuration"

### TABLE E-6 (Cont'd.) COMPARISON OF ODOR RATINGS
Cummins NTC-290

| Condition | Date | Conf.* | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|---|
| Idle | 8/5/75 | C | 2.6 | 1.0 | 0.9 | 0.5 | 0.4 |
| | 8/7/75 | C | 2.4 | 1.0 | 0.9 | 0.5 | 0.3 |
| | Average | | 2.5 | 1.0 | 0.9 | 0.5 | 0.4 |
| | 8/12/75 | L | 3.3 | 1.0 | 1.0 | 0.8 | 0.7 |
| | 8/14/75 | L | 3.2 | 1.0 | 0.9 | 0.6 | 0.8 |
| | Average | | 3.3 | 1.0 | 1.0 | 0.7 | 0.8 |
| Idle-Acceleration | 8/5/75 | C | 3.7 | 1.1 | 1.0 | 0.8 | 1.0 |
| | 8/7/75 | C | 3.5 | 1.0 | 1.0 | 0.7 | 0.7 |
| | Average | | 3.6 | 1.1 | 1.0 | 0.8 | 0.9 |
| | 8/12/75 | L | 3.5 | 1.0 | 1.0 | 0.7 | 0.8 |
| | 8/14/75 | L | 3.4 | 1.0 | 1.0 | 0.7 | 0.8 |
| | Average | | 3.5 | 1.0 | 1.0 | 0.7 | 0.8 |
| Acceleration | 8/5/75 | C | 3.1 | 1.0 | 1.0 | 0.7 | 0.5 |
| | 8/7/75 | C | 2.8 | 1.0 | 0.9 | 0.5 | 0.4 |
| | Average | | 3.0 | 1.0 | 1.0 | 0.6 | 0.5 |
| | 8/12/75 | L | 2.8 | 1.0 | 0.9 | 0.7 | 0.5 |
| | 8/14/75 | L | 3.0 | 1.0 | 0.9 | 0.8 | 0.6 |
| | Average | | 2.9 | 1.0 | 0.9 | 0.8 | 0.6 |
| Deceleration | 8/5/75 | C | 5.1 | 1.8 | 1.1 | 0.9 | 1.1 |
| | 8/7/75 | C | 5.2 | 1.7 | 1.2 | 1.0 | 1.2 |
| | Average | | 5.2 | 1.8 | 1.2 | 1.0 | 1.2 |
| | 8/12/75 | L | 4.6 | 1.5 | 1.0 | 1.0 | 1.1 |
| | 8/14/75 | L | 4.0 | 1.2 | 1.0 | 0.9 | 1.0 |
| | Average | | 4.3 | 1.4 | 1.0 | 1.0 | 1.1 |

---

*C - "Current Emission Configuration
L - "Low Emission Configuration"

## TABLE E-7. ODOR EVALUATION SUMMARY

Engine: Cummins NTC-290 (Current)
Date: August 5, 1975

Timing: Standard
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 5. | 1400 rpm | 2.6 | 1.0 | 0.9 | 0.5 | 0.6 |
| 10. | 2% load | 2.1 | 1.0 | 1.0 | 0.1 | 0.3 |
| 16. | | 2.1 | 0.9 | 0.9 | 0.4 | 0.3 |
| | | 2.3 | 1.0 | 0.9 | 0.3 | 0.4 |
| 3. | 1400 rpm | 2.0 | 0.9 | 1.0 | 0.1 | 0.3 |
| 14. | 50% load | 3.1 | 1.0 | 1.0 | 0.5 | 0.6 |
| 21. | | 2.4 | 1.0 | 0.9 | 0.8 | 0.1 |
| | | 2.5 | 1.0 | 1.0 | 0.5 | 0.3 |
| 1. | 1400 rpm | 2.1 | 1.0 | 1.0 | 0.3 | 0.3 |
| 9. | 100% load | 2.1 | 1.0 | 0.9 | 0.4 | 0.3 |
| 18. | | 2.1 | 1.0 | 0.9 | 0.4 | 0.3 |
| | | 2.1 | 1.0 | 0.9 | 0.4 | 0.3 |
| 7. | 2100 rpm | 2.6 | 1.0 | 0.6 | 0.6 | 0.5 |
| 13. | 2% load | 1.8 | 1.0 | 0.7 | 0.3 | 0.1 |
| 20. | | 2.4 | 0.9 | 0.6 | 1.0 | 0.3 |
| | | 2.3 | 1.0 | 0.6 | 0.6 | 0.3 |
| 2. | 2100 rpm | 2.4 | 0.9 | 1.0 | 0.3 | 0.3 |
| 8. | 50% load | 2.9 | 1.1 | 0.9 | 0.6 | 0.5 |
| 19. | | 1.8 | 0.9 | 0.6 | 0.5 | 0.1 |
| | | 2.4 | 1.0 | 0.8 | 0.5 | 0.3 |
| 6. | 2100 rpm | 3.3 | 1.0 | 0.8 | 0.6 | 0.9 |
| 11. | 100% load | 3.0 | 1.0 | 1.0 | 0.6 | 0.5 |
| 15. | | 2.9 | 1.0 | 0.9 | 0.6 | 0.5 |
| | | 3.1 | 1.0 | 0.9 | 0.6 | 0.6 |
| 4. | Idle | 2.8 | 1.1 | 0.9 | 0.4 | 0.5 |
| 12. | | 2.5 | 1.0 | 0.8 | 0.6 | 0.4 |
| 17. | | 2.4 | 0.9 | 1.0 | 0.6 | 0.3 |
| | | 2.6 | 1.0 | 0.9 | 0.5 | 0.4 |
| 22. | Idle- | 3.5 | 1.0 | 1.0 | 0.8 | 0.9 |
| 27. | Acceleration | 3.9 | 1.1 | 0.9 | 0.9 | 1.0 |
| 29. | | 3.6 | 1.1 | 1.0 | 0.8 | 1.0 |
| 31. | | 3.9 | 1.2 | 1.0 | 0.8 | 1.0 |
| | | 3.7 | 1.1 | 1.0 | 0.8 | 1.0 |
| 24. | Acceleration | 3.1 | 1.0 | 0.8 | 0.8 | 0.5 |
| 26. | | 2.7 | 0.9 | 1.0 | 0.3 | 0.4 |
| 28. | | 2.9 | 1.1 | 1.0 | 0.6 | 0.4 |
| 33. | | 3.6 | 1.1 | 1.0 | 0.9 | 0.8 |
| | | 3.1 | 1.0 | 1.0 | 0.7 | 0.5 |
| 23. | Deceleration | 4.4 | 1.6 | 1.0 | 0.9 | 0.9 |
| 25. | | 4.8 | 1.8 | 1.0 | 0.9 | 1.0 |
| 30. | | 5.3 | 2.0 | 1.1 | 0.9 | 1.1 |
| 32. | | 5.8 | 1.9 | 1.4 | 1.0 | 1.2 |
| | | 5.1 | 1.8 | 1.1 | 0.9 | 1.1 |

## TABLE E-8. ODOR EVALUATION SUMMARY

Engine: Cummins NTC-290 (Current)
Date: August 7, 1975

Timing: Standard
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 6. | 1400 rpm | 2.5 | 0.8 | 1.0 | 0.7 | 0.2 |
| 12. | 2% load | 2.3 | 1.0 | 0.7 | 0.5 | 0.2 |
| 17. | | 2.5 | 1.0 | 1.0 | 0.5 | 0.2 |
| | | 2.4 | 0.9 | 0.9 | 0.6 | 0.2 |
| 1. | 1400 rpm | 2.0 | 0.8 | 0.8 | 0.5 | 0.2 |
| 8. | 50% load | 2.3 | 1.0 | 0.8 | 0.3 | 0.3 |
| 19. | | 2.0 | 0.8 | 0.5 | 0.5 | 0.2 |
| | | 2.1 | 0.9 | 0.7 | 0.4 | 0.2 |
| 4. | 1400 rpm | 2.0 | 1.0 | 0.7 | 0.4 | 0.1 |
| 13. | 100% load | 1.9 | 0.9 | 0.8 | 0.1 | 0.3 |
| 21. | | 1.9 | 0.9 | 0.8 | 0.1 | 0.3 |
| | | 1.9 | 0.9 | 0.8 | 0.2 | 0.2 |
| 2. | 2100 rpm | 2.5 | 1.0 | 1.0 | 0.3 | 0.3 |
| 9. | 2% load | 2.2 | 1.0 | 0.7 | 0.5 | 0.3 |
| 15. | | 2.1 | 0.8 | 0.8 | 0.3 | 0.3 |
| | | 2.3 | 0.9 | 0.8 | 0.4 | 0.3 |
| 3. | 2100 rpm | 2.5 | 0.8 | 1.0 | 0.3 | 0.3 |
| 14. | 50% load | 2.8 | 1.0 | 1.0 | 0.5 | 0.3 |
| 20. | | 2.5 | 0.8 | 0.8 | 0.7 | 0.2 |
| | | 2.6 | 0.9 | 0.9 | 0.5 | 0.3 |
| 7. | 2100 rpm | 3.4 | 1.0 | 1.0 | 0.7 | 1.0 |
| 11. | 100% load | 2.7 | 1.0 | 0.9 | 0.6 | 0.4 |
| 16. | | 2.3 | 1.0 | 1.0 | 0.3 | 0.4 |
| | | 2.8 | 1.0 | 1.0 | 0.5 | 0.6 |
| 5. | Idle | 2.5 | 1.0 | 0.9 | 0.5 | 0.4 |
| 10. | | 2.5 | 1.0 | 0.9 | 0.6 | 0.3 |
| 18. | | 2.2 | 0.9 | 0.9 | 0.4 | 0.3 |
| | | 2.4 | 1.0 | 0.9 | 0.5 | 0.3 |
| 24. | Idle-Acceleration | 3.4 | 1.0 | 1.0 | 0.4 | 1.0 |
| 26. | | 4.1 | 1.1 | 1.0 | 0.9 | 1.1 |
| 28. | | 2.7 | 1.0 | 1.0 | 0.4 | 0.1 |
| 31. | | 3.6 | 1.0 | 1.0 | 1.0 | 0.7 |
| | | 3.5 | 1.0 | 1.0 | 0.7 | 0.7 |
| 23. | Acceleration | 2.9 | 1.0 | 0.9 | 0.4 | 0.4 |
| 27. | | 2.7 | 1.0 | 1.0 | 0.3 | 0.4 |
| 30. | | 2.7 | 1.0 | 0.9 | 0.7 | 0.2 |
| 32. | | 2.7 | 1.0 | 0.9 | 0.7 | 0.6 |
| | | 2.8 | 1.0 | 0.9 | 0.5 | 0.4 |
| 22. | Deceleration | 5.0 | 1.7 | 1.3 | 0.9 | 1.1 |
| 25. | | 5.7 | 1.7 | 1.3 | 1.0 | 1.3 |
| 29. | | 4.6 | 1.7 | 1.0 | 0.9 | 1.0 |
| 33. | | 5.3 | 1.7 | 1.0 | 1.0 | 1.3 |
| | | 5.2 | 1.7 | 1.2 | 1.0 | 1.2 |

## TABLE E-9. ODOR EVALUATION SUMMARY

Engine: Cummins NTC-290 (Low)
Date: August 12, 1975

Timing: Variable
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 2. | 1400 rpm | 2.3 | 1.0 | 0.9 | 0.3 | 0.3 |
| 7. | 2% load | 2.4 | 1.0 | 0.9 | 0.5 | 0.3 |
| | | 2.5 | 1.0 | 1.0 | 0.4 | 0.4 |
| | | 2.4 | 1.0 | 0.9 | 0.4 | 0.3 |
| 10. | 1400 rpm | 2.3 | 1.0 | 0.8 | 0.4 | 0.3 |
| 15. | 50% load | 3.1 | 1.0 | 1.0 | 0.5 | 0.6 |
| 20. | | 2.6 | 1.0 | 1.0 | 0.5 | 0.6 |
| | | 2.7 | 1.0 | 0.9 | 0.5 | 0.5 |
| 6. | 1400 rpm | 1.9 | 0.8 | 0.8 | 0.6 | 0.3 |
| 11. | 100% load | 2.1 | 0.9 | 0.6 | 0.8 | 0.1 |
| 18. | | 2.9 | 1.0 | 0.8 | 0.8 | 0.5 |
| | | 2.3 | 0.9 | 0.7 | 0.7 | 0.3 |
| 5. | 2100 rpm | 2.4 | 0.9 | 0.9 | 0.4 | 0.4 |
| 9. | 2% load | 2.5 | 1.0 | 0.9 | 0.5 | 0.3 |
| 19. | | 2.3 | 1.0 | 1.0 | 0.3 | 0.3 |
| | | 2.4 | 1.0 | 0.9 | 0.4 | 0.3 |
| 4. | 2100 rpm | 2.8 | 1.0 | 0.9 | 0.8 | 0.1 |
| 13. | 50% load | 3.6 | 1.0 | 1.0 | 1.0 | 0.9 |
| 21. | | 2.5 | 1.0 | 1.0 | 0.3 | 0.4 |
| | | 3.0 | 1.0 | 1.0 | 0.7 | 0.5 |
| 1. | 2100 rpm | 1.9 | 1.0 | 0.4 | 0.6 | 0.1 |
| 8. | 100% load | 1.6 | 0.8 | 0.8 | 0.4 | 0.1 |
| 16. | | 2.3 | 0.9 | 1.0 | 0.5 | 0.3 |
| | | 1.9 | 0.9 | 0.7 | 0.5 | 0.2 |
| 3. | Idle | 3.0 | 0.9 | 1.0 | 0.8 | 0.4 |
| 12. | | 3.3 | 1.0 | 1.0 | 0.9 | 0.6 |
| 17. | | 3.5 | 1.0 | 1.0 | 0.6 | 1.0 |
| | | 3.3 | 1.0 | 1.0 | 0.8 | 0.7 |
| 24. | Idle-Acceleration | 3.4 | 1.0 | 1.0 | 0.6 | 0.8 |
| 26. | | 3.6 | 1.0 | 1.0 | 0.6 | 0.9 |
| 30. | | 3.8 | 1.0 | 1.0 | 0.5 | 0.8 |
| 33. | | 3.1 | 1.0 | 1.0 | 1.0 | 0.6 |
| | | 3.5 | 1.0 | 1.0 | 0.7 | 0.8 |
| 22. | Acceleration | 2.1 | 1.0 | 0.8 | 0.6 | 0.1 |
| 27. | | 2.6 | 0.9 | 0.9 | 0.5 | 0.3 |
| 29. | | 3.4 | 1.1 | 1.0 | 1.0 | 0.9 |
| 32. | | 3.0 | 1.0 | 1.0 | 0.8 | 0.6 |
| | | 2.8 | 1.0 | 0.9 | 0.7 | 0.5 |
| 23. | Deceleration | 4.1 | 1.1 | 1.0 | 1.0 | 1.0 |
| 25. | | 4.5 | 1.4 | 1.0 | 1.0 | 1.1 |
| 28. | | 5.0 | 1.9 | 1.0 | 1.0 | 1.1 |
| 31. | | 4.9 | 1.6 | 1.0 | 0.9 | 1.1 |
| | | 4.6 | 1.5 | 1.0 | 1.0 | 1.1 |

## TABLE E-10. ODOR EVALUATION SUMMARY

Engine: Cummins NTC-290 (Low)
Date: August 14, 1975

Timing: Variable
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 3. | 1400 rpm | 2.4 | 1.0 | 0.8 | 0.6 | 0.4 |
| 9. | 2% load | 2.5 | 1.0 | 0.9 | 0.5 | 0.4 |
| 15. | | 2.4 | 1.0 | 0.6 | 0.5 | 0.4 |
| | | 2.4 | 1.0 | 0.8 | 0.5 | 0.4 |
| 7. | 1400 rpm | 1.8 | 0.8 | 0.8 | 0.4 | 0 |
| 13. | 50% load | 3.1 | 1.0 | 1.0 | 0.8 | 0.4 |
| 19. | | 2.6 | 1.0 | 0.9 | 0.5 | 0.6 |
| | | 2.5 | 0.9 | 0.9 | 0.6 | 0.3 |
| 2. | 1400 rpm | 2.4 | 1.0 | 1.0 | 0.4 | 0.3 |
| 10. | 100% load | 2.3 | 1.0 | 0.8 | 0.4 | 0.3 |
| 21. | | 2.1 | 1.0 | 0.6 | 0.5 | 0.1 |
| | | 2.3 | 1.0 | 0.8 | 0.4 | 0.2 |
| 11. | 2100 rpm | 1.9 | 1.0 | 0.8 | 0.3 | 0.3 |
| 17. | 2% load | 1.9 | 0.9 | 0.6 | 0.4 | 0 |
| 20. | | 2.1 | 1.0 | 0.8 | 0.3 | 0.4 |
| | | 2.0 | 1.0 | 0.7 | 0.3 | 0.2 |
| 1. | 2100 rpm | 2.9 | 1.0 | 1.0 | 0.6 | 0.5 |
| 8. | 50% load | 3.1 | 1.0 | 0.9 | 1.0 | 0.4 |
| 12. | | 2.9 | 1.0 | 1.0 | 0.5 | 0.6 |
| | | 3.0 | 1.0 | 1.0 | 0.7 | 0.5 |
| 4. | 2100 rpm | 2.6 | 1.1 | 1.0 | 0.5 | 0.3 |
| 6. | 100% load | 2.0 | 1.0 | 1.0 | 0.1 | 0.1 |
| 16. | | 2.3 | 1.0 | 1.0 | 0.5 | 0.3 |
| | | 2.3 | 1.0 | 1.0 | 0.4 | 0.2 |
| 5. | Idle | 3.7 | 1.0 | 0.9 | 0.6 | 1.0 |
| 14. | | 2.9 | 1.0 | 0.9 | 0.5 | 0.5 |
| 18. | | 3.1 | 1.0 | 1.0 | 0.6 | 0.8 |
| | | 3.2 | 1.0 | 0.9 | 0.6 | 0.8 |
| 22. | Idle- | 2.9 | 1.0 | 1.0 | 0.5 | 0.5 |
| 26. | Acceleration | 4.1 | 1.0 | 1.0 | 1.0 | 1.0 |
| 30. | | 3.3 | 1.0 | 1.0 | 0.5 | 0.9 |
| 33. | | 3.4 | 1.0 | 1.0 | 0.8 | 0.9 |
| | | 3.4 | 1.0 | 1.0 | 0.7 | 0.8 |
| 23. | Acceleration | 2.1 | 0.9 | 0.8 | 0.5 | 0.3 |
| 25. | | 2.9 | 1.0 | 0.8 | 0.8 | 0.4 |
| 28. | | 3.8 | 1.0 | 1.0 | 0.9 | 1.0 |
| 31. | | 3.3 | 1.0 | 1.0 | 0.9 | 0.6 |
| | | 3.0 | 1.0 | 0.9 | 0.8 | 0.6 |
| 24. | Deceleration | 3.5 | 1.0 | 0.9 | 0.8 | 1.0 |
| 27. | | 4.5 | 1.4 | 1.0 | 1.0 | 1.0 |
| 29. | | 4.1 | 1.0 | 1.0 | 1.0 | 1.0 |
| 32. | | 4.0 | 1.3 | 1.0 | 0.9 | 1.0 |
| | | 4.0 | 1.2 | 1.0 | 0.9 | 1.0 |

## TABLE E-11. SUMMARY OF DAILY ODOR TEST AVERAGES
### Detroit Diesel 8V-71 TA

| Condition | Date | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 1400 rpm 2% load | 1/12/76 | 3.2 | 1.0 | 1.0 | 0.8 | 0.6 |
| | 1/14/76 | 2.6 | 1.0 | 0.9 | 0.5 | 0.7 |
| | 1/16/76 | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| | Average | 2.8 | 1.0 | 0.9 | 0.6 | 0.6 |
| 1400 rpm 50% load | 1/12/76 | 2.9 | 1.0 | 0.9 | 0.8 | 0.5 |
| | 1/14/76 | 2.3 | 0.9 | 0.9 | 0.5 | 0.4 |
| | 1/16/76 | 2.4 | 1.0 | 0.8 | 0.5 | 0.2 |
| | Average | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| 1400 rpm 100% load | 1/12/76 | 2.8 | 1.0 | 1.0 | 0.7 | 0.5 |
| | 1/14/76 | 2.7 | 1.0 | 1.0 | 0.6 | 0.5 |
| | 1/16/76 | 2.9 | 1.0 | 0.9 | 0.8 | 0.5 |
| | Average | 2.8 | 1.0 | 1.0 | 0.7 | 0.5 |
| 2100 rpm 2% load | 1/12/76 | 2.9 | 1.0 | 0.9 | 0.7 | 0.6 |
| | 1/14/76 | 2.3 | 0.9 | 0.8 | 0.6 | 0.3 |
| | 1/16/76 | 2.6 | 1.0 | 1.0 | 0.6 | 0.5 |
| | Average | 2.6 | 1.0 | 0.9 | 0.6 | 0.5 |
| 2100 rpm 50% load | 1/12/76 | 2.8 | 0.9 | 1.0 | 0.7 | 0.4 |
| | 1/14/76 | 2.3 | 0.9 | 0.8 | 0.6 | 0.3 |
| | 1/16/76 | 2.4 | 1.0 | 0.8 | 0.7 | 0.2 |
| | Average | 2.5 | 0.9 | 0.9 | 0.7 | 0.3 |
| 2100 rpm 100% load | 1/12/76 | 2.8 | 1.0 | 0.9 | 0.7 | 0.5 |
| | 1/14/76 | 2.8 | 1.0 | 0.9 | 0.7 | 0.7 |
| | 1/16/76 | 2.5 | 1.0 | 1.0 | 0.5 | 0.3 |
| | Average | 2.7 | 1.0 | 0.9 | 0.6 | 0.5 |
| Idle | 1/12/76 | 3.1 | 0.9 | 0.9 | 0.8 | 0.5 |
| | 1/14/76 | 2.8 | 1.0 | 0.9 | 0.6 | 0.6 |
| | 1/16/76 | 2.4 | 1.0 | 0.8 | 0.7 | 0.2 |
| | Average | 2.8 | 1.0 | 0.9 | 0.7 | 0.4 |
| Idle-Acceleration | 1/12/76 | 3.8 | 1.1 | 1.0 | 0.8 | 0.7 |
| | 1/14/76 | 3.9 | 1.1 | 1.0 | 0.9 | 1.0 |
| | 1/16/76 | 3.7 | 1.1 | 1.0 | 0.9 | 0.8 |
| | Average | 3.8 | 1.1 | 1.0 | 0.9 | 0.8 |
| Acceleration | 1/12/76 | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| | 1/14/76 | 2.9 | 1.1 | 0.9 | 0.7 | 0.7 |
| | 1/16/76 | 3.2 | 1.1 | 1.0 | 0.8 | 0.7 |
| | Average | 3.0 | 1.1 | 0.9 | 0.7 | 0.6 |
| Deceleration | 1/12/76 | 2.8 | 1.0 | 1.0 | 0.6 | 0.5 |
| | 1/14/76 | 3.1 | 1.0 | 1.0 | 0.8 | 0.7 |
| | 1/16/76 | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |
| | Average | 2.9 | 1.0 | 1.0 | 0.7 | 0.6 |

## TABLE E-12. ODOR EVALUATION SUMMARY

Engine: Detroit Diesel 8V-71 TA
Date: January 12, 1976

Injectors: N-75
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 5. | 1400 rpm 2% load | 3.4 | 1.1 | 1.0 | 0.8 | 0.7 |
| 10. | | 2.7 | 1.0 | 0.9 | 0.8 | 0.3 |
| 16. | | 3.4 | 1.0 | 1.0 | 0.8 | 0.7 |
| | | 3.2 | 1.0 | 1.0 | 0.8 | 0.6 |
| 3. | 1400 rpm 50% load | 2.6 | 0.9 | 1.0 | 0.8 | 0.2 |
| 14. | | 3.0 | 1.0 | 0.9 | 0.7 | 0.7 |
| 21. | | 3.0 | 1.0 | 0.9 | 0.8 | 0.6 |
| | | 2.9 | 1.0 | 0.9 | 0.8 | 0.5 |
| 1. | 1400 rpm 100% load | 2.6 | 0.9 | 1.0 | 0.4 | 0.6 |
| 9. | | 3.2 | 1.0 | 1.0 | 1.0 | 0.4 |
| 18. | | 2.6 | 1.0 | 1.0 | 0.6 | 0.6 |
| | | 2.8 | 1.0 | 1.0 | 0.7 | 0.5 |
| 7. | 2100 rpm 2% load | 3.3 | 1.0 | 0.9 | 0.9 | 0.7 |
| 13. | | 2.8 | 1.0 | 1.0 | 0.8 | 0.4 |
| 20. | | 2.7 | 0.9 | 0.8 | 0.4 | 0.7 |
| | | 2.9 | 1.0 | 0.9 | 0.7 | 0.6 |
| 2. | 2100 rpm 50% load | 2.9 | 0.8 | 1.0 | 0.8 | 0.3 |
| 8. | | 2.6 | 1.0 | 1.0 | 0.6 | 0.3 |
| 19. | | 3.0 | 1.0 | 1.0 | 0.6 | 0.7 |
| | | 2.8 | 0.9 | 1.0 | 0.7 | 0.4 |
| 6. | 2100 rpm 100% load | 2.8 | 1.0 | 0.9 | 0.7 | 0.4 |
| 11. | | 2.6 | 1.0 | 1.0 | 0.6 | 0.3 |
| 15. | | 3.0 | 1.0 | 0.9 | 0.7 | 0.7 |
| | | 2.8 | 1.0 | 0.9 | 0.7 | 0.5 |
| 4. | Idle | 3.0 | 1.0 | 1.0 | 0.8 | 0.4 |
| 12. | | 3.2 | 0.8 | 0.9 | 0.8 | 0.4 |
| 17. | | 3.2 | 1.0 | 0.9 | 0.8 | 0.8 |
| | | 3.1 | 0.9 | 0.9 | 0.8 | 0.5 |
| 24. | Idle-Acceleration | 3.6 | 1.0 | 0.9 | 0.6 | 0.9 |
| 26. | | 3.7 | 1.1 | 1.0 | 0.8 | 0.8 |
| 28. | | 4.0 | 1.2 | 1.0 | 0.8 | 1.0 |
| 31. | | 4.0 | 1.1 | 1.0 | 1.0 | 0.9 |
| | | 3.8 | 1.1 | 1.0 | 0.8 | 0.9 |
| 23. | Acceleration | 3.0 | 1.0 | 0.9 | 0.6 | 0.9 |
| 27. | | 2.8 | 1.1 | 0.9 | 0.4 | 0.4 |
| 30. | | 3.0 | 1.0 | 1.0 | 0.6 | 0.6 |
| 32. | | 2.2 | 1.0 | 0.9 | 0.6 | 0.2 |
| | | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| 22. | Deceleration | 2.6 | 1.0 | 1.0 | 0.4 | 0.6 |
| 25. | | 2.7 | 1.0 | 1.0 | 0.6 | 0.4 |
| 29. | | 3.0 | 1.0 | 1.0 | 0.9 | 0.4 |
| 33. | | 2.8 | 1.0 | 1.0 | 0.4 | 0.4 |
| | | 2.8 | 1.0 | 1.0 | 0.6 | 0.5 |

## TABLE E-13. ODOR EVALUATION SUMMARY

Engine: Detroit Diesel 8V-71 TA
Date: January 14, 1976

Injectors: N-75
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 6. | 1400 rpm 2% load | 1.9 | 0.9 | 0.8 | 0.3 | 0.5 |
| 12. | | 2.9 | 1.0 | 1.0 | 0.7 | 0.7 |
| 17. | | 2.9 | 1.0 | 1.0 | 0.6 | 0.8 |
| | | 2.6 | 1.0 | 0.9 | 0.5 | 0.7 |
| 1. | 1400 rpm 50% load | 2.4 | 0.9 | 0.9 | 0.6 | 0.5 |
| 8. | | 2.2 | 1.0 | 0.8 | 0.3 | 0.3 |
| 19. | | 2.3 | 0.9 | 0.9 | 0.7 | 0.3 |
| | | 2.3 | 0.9 | 0.9 | 0.5 | 0.4 |
| 4. | 1400 rpm 100% load | 3.1 | 1.0 | 1.0 | 0.7 | 0.8 |
| 13. | | 2.7 | 1.0 | 0.9 | 0.6 | 0.3 |
| 21. | | 2.3 | 1.0 | 1.0 | 0.4 | 0.4 |
| | | 2.7 | 1.0 | 1.0 | 0.6 | 0.5 |
| 2. | 2100 rpm 2% load | 2.2 | 0.8 | 0.8 | 0.5 | 0.3 |
| 9. | | 2.1 | 1.0 | 0.7 | 0.4 | 0.2 |
| 15. | | 2.6 | 1.0 | 0.9 | 0.8 | 0.4 |
| | | 2.3 | 0.9 | 0.8 | 0.6 | 0.3 |
| 3. | 2100 rpm 50% load | 2.0 | 0.8 | 0.6 | 0.3 | 0.1 |
| 14. | | 2.7 | 1.0 | 0.9 | 0.7 | 0.6 |
| 20. | | 2.1 | 1.0 | 0.8 | 0.7 | 0.3 |
| | | 2.3 | 0.9 | 0.8 | 0.6 | 0.3 |
| 7. | 2100 rpm 100% load | 2.7 | 1.0 | 0.8 | 0.6 | 0.6 |
| 11. | | 3.1 | 1.0 | 0.9 | 0.7 | 0.9 |
| 16. | | 2.6 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 2.8 | 1.0 | 0.9 | 0.7 | 0.7 |
| 5. | Idle | 2.5 | 1.0 | 0.9 | 0.7 | 0.3 |
| 10. | | 3.1 | 1.1 | 1.0 | 0.7 | 0.8 |
| 18. | | 2.7 | 1.0 | 0.9 | 0.4 | 0.6 |
| | | 2.8 | 1.0 | 0.9 | 0.6 | 0.6 |
| 23. | Idle-Acceleration | 3.6 | 1.0 | 1.0 | 0.9 | 1.0 |
| 26. | | 4.1 | 1.1 | 1.0 | 0.9 | 1.0 |
| 29. | | 3.6 | 1.0 | 1.0 | 0.8 | 1.0 |
| 31. | | 4.4 | 1.3 | 1.0 | 1.0 | 1.0 |
| | | 3.9 | 1.1 | 1.0 | 0.9 | 1.0 |
| 22. | Acceleration | 2.8 | 1.0 | 0.8 | 0.6 | 0.5 |
| 24. | | 2.9 | 1.0 | 0.9 | 0.8 | 0.8 |
| 28. | | 2.9 | 1.0 | 0.8 | 0.9 | 0.8 |
| 32. | | 3.0 | 1.4 | 0.9 | 0.6 | 0.5 |
| | | 2.9 | 1.1 | 0.9 | 0.7 | 0.7 |
| 25. | Deceleration | 2.5 | 1.0 | 0.9 | 0.8 | 0.5 |
| 27. | | 3.5 | 1.0 | 1.0 | 0.8 | 0.9 |
| 30. | | 3.3 | 1.0 | 0.9 | 0.8 | 0.9 |
| 33. | | 2.9 | 1.0 | 1.0 | 0.6 | 0.4 |
| | | 3.1 | 1.0 | 1.0 | 0.8 | 0.7 |

## TABLE E-14. ODOR EVALUATION SUMMARY

Engine: Detroit Diesel 8V-71 TA
Date: January 16, 1976

Injectors: N-75
Dilution: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 1. | 1400 rpm | 2.3 | 0.9 | 0.9 | 0.6 | 0.3 |
| 9. | 2% load | 2.4 | 1.0 | 1.0 | 0.7 | 0.3 |
| 16. | | 2.9 | 1.0 | 0.9 | 0.6 | 0.6 |
| | | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| 6. | 1400 rpm | 2.7 | 1.0 | 1.0 | 0.4 | 0.4 |
| 13. | 50% load | 2.3 | 1.0 | 0.7 | 0.4 | 0 |
| 19. | | 2.3 | 1.0 | 0.7 | 0.6 | 0.1 |
| | | 2.4 | 1.0 | 0.8 | 0.5 | 0.2 |
| 4. | 1400 rpm | 2.7 | 1.0 | 0.9 | 0.7 | 0.4 |
| 10. | 100% load | 2.7 | 1.0 | 0.9 | 0.7 | 0.1 |
| 17. | | 3.4 | 1.0 | 0.9 | 0.9 | 0.9 |
| | | 2.9 | 1.0 | 0.9 | 0.8 | 0.5 |
| 5. | 2100 rpm | 2.4 | 0.9 | 0.9 | 0.7 | 0.4 |
| 11. | 2% load | 2.7 | 1.0 | 1.0 | 0.6 | 0.6 |
| 14. | | 2.7 | 1.0 | 1.0 | 0.6 | 0.6 |
| | | 2.6 | 1.0 | 1.0 | 0.6 | 0.5 |
| 8. | 2100 rpm | 2.4 | 1.0 | 0.9 | 0.7 | 0.1 |
| 15. | 50% load | 2.3 | 1.0 | 0.6 | 0.7 | 0.4 |
| 21. | | 2.4 | 1.0 | 0.9 | 0.6 | 0.1 |
| | | 2.4 | 1.0 | 0.8 | 0.7 | 0.2 |
| 2. | 2100 rpm | 2.4 | 1.0 | 1.0 | 0.6 | 0.3 |
| 7. | 100% load | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |
| 20. | | 2.3 | 1.0 | 1.0 | 0.3 | 0.1 |
| | | 2.5 | 1.0 | 1.0 | 0.5 | 0.3 |
| 3. | Idle | 2.0 | 1.0 | 0.9 | 0.6 | 0.3 |
| 12. | | 2.9 | 1.0 | 0.7 | 0.9 | 0.3 |
| 18. | | 2.3 | 1.0 | 0.9 | 0.6 | 0.1 |
| | | 2.4 | 1.0 | 0.8 | 0.7 | 0.2 |
| 24. | Idle- | 3.4 | 1.0 | 1.0 | 0.9 | 0.6 |
| 26. | Acceleration | 3.7 | 1.0 | 1.0 | 0.9 | 0.9 |
| 29. | | 4.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 32. | | 3.8 | 1.2 | 1.0 | 0.7 | 0.8 |
| | | 3.7 | 1.1 | 1.0 | 0.9 | 0.8 |
| 23. | Acceleration | 3.4 | 1.0 | 1.0 | 0.9 | 0.7 |
| 27. | | 2.6 | 1.0 | 1.0 | 0.4 | 0.6 |
| 31. | | 3.5 | 1.0 | 1.0 | 1.0 | 0.7 |
| 33. | | 3.3 | 1.2 | 1.0 | 0.8 | 0.7 |
| | | 3.2 | 1.1 | 1.0 | 0.8 | 0.7 |
| 22. | Deceleration | 2.7 | 0.9 | 1.0 | 0.7 | 0.4 |
| 25. | | 2.7 | 1.0 | 1.0 | 0.7 | 0.6 |
| 28. | | 2.7 | 1.0 | 1.0 | 0.6 | 0.4 |
| 30. | | 3.3 | 1.0 | 1.0 | 0.4 | 1.0 |
| | | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |

# APPENDIX F

# INSTRUMENTAL-WET CHEMICAL EXHAUST DATA TAKEN DURING ODOR TEST OF FIVE HEAVY DUTY ENGINES

## TABLE F-1. COMPARISON OF GASEOUS EMISSIONS
### Detroit Diesel 6V-71 Engine

| | | | | | | NDIR | CL | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Date | Conf. | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, μg/l | LCO, μg/l | TIA |
| 900 rpm 2% load | 8/19/75 | LSN 60 | 203 | 144 | 1.2 | 162 | 142 | 181 | 23.5 | 1.0 | 1.0 |
| | 8/21/75 | LSN 60 | 147 | 145 | 1.1 | 158 | 140 | 174 | 16.1 | 1.3 | 1.1 |
| | Average | | 175 | 145 | 1.2 | 160 | 141 | 177 | 19.8 | 1.2 | 1.1 |
| | 8/26/75 | B60E | 120 | 207 | 1.1 | 71 | 66 | 89 | 19.7 | 2.4 | 1.4 |
| | 8/28/75 | B60E | 122 | 191 | 1.1 | 73 | 69 | 95 | 17.0 | 2.4 | 1.4 |
| | Average | | 121 | 199 | 1.1 | 72 | 68 | 92 | 18.4 | 2.4 | 1.4 |
| 900 rpm 50% load | 8/19/75 | LSN 60 | 240 | 99 | 3.3 | 712 | 652 | 707 | 26.4 | 0.9 | 0.9 |
| | 8/21/75 | LSN 60 | 229 | 97 | 3.3 | 726 | 652 | 778 | 20.9 | 1.3 | 1.1 |
| | Average | | 235 | 98 | 3.3 | 719 | 652 | 743 | 23.7 | 1.1 | 1.0 |
| | 8/26/75 | B60E | 75 | 89 | 3.2 | 398 | 364 | 396 | 11.4 | 1.2 | 1.1 |
| | 8/28/75 | B60E | 79 | 82 | 3.3 | 411 | 390 | 421 | 10.0 | 1.4 | 1.1 |
| | Average | | 77 | 86 | 3.3 | 405 | 377 | 409 | 10.7 | 1.3 | 1.1 |
| 900 rpm 100% load | 8/19/75 | LSN 60 | 454 | 7851 | 6.1 | 830 | 762 | 800 | 59.7 | 2.3 | 1.4 |
| | 8/21/75 | LSN 60 | 423 | 7833 | 6.2 | 787 | 741 | 778 | 50.4 | 3.8 | 1.6 |
| | Average | | 439 | 7842 | 6.2 | 809 | 752 | 789 | 55.1 | 3.1 | 1.5 |
| | 8/26/75 | B60E | 212 | 3621 | 6.0 | 1031 | 933 | 968 | 26.6 | 2.2 | 1.3 |
| | 8/28/75 | B60E | 203 | 3410 | 6.4 | 1052 | 987 | 1020 | 24.9 | 2.8 | 1.4 |
| | Average | | 208 | 3516 | 6.2 | 1042 | 960 | 994 | 25.8 | 2.5 | 1.4 |
| 1500 rpm 2% load | 8/19/75 | LSN 60 | 233 | 112 | 1.5 | 191 | 160 | 194 | 26.1 | 0.9 | 0.9 |
| | 8/21/75 | LSN 60 | 164 | 121 | 1.5 | 174 | 158 | 193 | 20.2 | 1.6 | 1.2 |
| | Average | | 199 | 117 | 1.5 | 183 | 159 | 194 | 23.2 | 1.3 | 1.1 |
| | 8/26/75 | B60E | 126 | 235 | 1.5 | 73 | 66 | 93 | 20.8 | 2.6 | 1.4 |
| | 8/28/75 | B60E | 133 | 215 | 1.5 | 75 | 71 | 97 | 18.0 | 2.6 | 1.4 |
| | Average | | 130 | 225 | 1.5 | 74 | 69 | 95 | 19.4 | 2.6 | 1.4 |
| 1500 rpm 50% load | 8/19/75 | LSN 60 | 253 | 97 | 3.4 | 619 | 574 | 623 | 28.9 | 1.1 | 1.0 |
| | 8/21/75 | LSN 60 | 264 | 93 | 3.4 | 636 | 586 | 635 | 22.5 | 1.5 | 1.2 |
| | Average | | 259 | 95 | 3.4 | 627 | 580 | 629 | 25.7 | 1.3 | 1.1 |
| | 8/26/75 | B60E | 100 | 84 | 3.4 | 298 | 276 | 303 | 16.1 | 1.5 | 1.2 |
| | 8/28/75 | B60E | 84 | 76 | 3.4 | 331 | 294 | 324 | 9.8 | 1.6 | 1.2 |
| | Average | | 92 | 80 | 3.4 | 315 | 285 | 314 | 13.0 | 1.6 | 1.2 |
| 1500 rpm 100% load | 8/19/75 | LSN 60 | 345 | 1829 | 6.2 | 1132 | 1051 | 1105 | 54.0 | 2.4 | 1.4 |
| | 8/21/75 | LSN 60 | 321 | 1710 | 6.2 | 1139 | 1062 | 1117 | 43.7 | 3.5 | 1.5 |
| | Average | | 333 | 1770 | 6.2 | 1136 | 1057 | 1111 | 48.9 | 3.0 | 1.5 |
| | 8/26/75 | B60E | 135 | 1353 | 6.1 | 852 | 795 | 827 | 27.2 | 3.0 | 1.5 |
| | 8/28/75 | B60E | 151 | 1181 | 6.2 | 883 | 850 | 891 | 21.8 | 3.0 | 1.5 |
| | Average | | 143 | 1267 | 6.2 | 868 | 823 | 859 | 24.5 | 3.0 | 1.5 |
| Idle | 8/19/75 | LSN 60 | 202 | 126 | 0.9 | 191 | 160 | 200 | 20.3 | 0.8 | 0.9 |
| | 8/21/75 | LSN 60 | 149 | 126 | 1.0 | 174 | 160 | 198 | 15.4 | 1.2 | 1.1 |
| | Average | | 176 | 126 | 1.0 | 183 | 160 | 199 | 17.9 | 1.0 | 1.0 |
| | 8/26/75 | B60E | 132 | 129 | 0.9 | 97 | 92 | 113 | 18.7 | 1.6 | 1.2 |
| | 8/28/75 | B60E | 159 | 135 | 0.9 | 102 | 97 | 121 | 15.5 | 1.6 | 1.2 |
| | Average | | 146 | 132 | 0.9 | 100 | 95 | 117 | 17.1 | 1.6 | 1.2 |

## TABLE F-2. GASEOUS EMISSIONS SUMMARY

Engine: Detroit Diesel 6V-71
Date: August 19, 1975

Injectors: LSN 60
Dilution: 100:1

| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NDIR NO, ppm | CL NO, ppm | CL $NO_x$, ppm | DOAS Results LCA, $\mu g/l$ | DOAS Results LCO, $\mu g/l$ | DOAS Results TIA |
|---|---|---|---|---|---|---|---|---|---|---|
| 900 rpm | 3. | 230 | 148 | 1.2 | 146 | 147 | 178 | 23.4 | 1.0 | 1.0 |
| 2% load | 13. | 202 | 143 | 1.1 | 172 | 143 | 189 | 22.4 | 0.9 | 1.0 |
|  | 17. | 176 | 140 | 1.3 | 168 | 137 | 176 | 24.8 | 1.1 | 1.0 |
| Average |  | 203 | 144 | 1.2 | 162 | 142 | 181 | 23.5 | 1.0 | 1.0 |
| 900 rpm | 1. | 224 | 102 | 3.3 | 685 | 642 | 697 | 27.6 | 1.0 | 1.0 |
| 50% load | 6. | 250 | 88 | 3.3 | 721 | 663 | 713 | 24.7 | 0.7 | 0.8 |
|  | 11. | 246 | 108 | 3.2 | 731 | 652 | 712 | 27.0 | 1.0 | 1.0 |
| Average |  | 240 | 99 | 3.3 | 712 | 652 | 707 | 26.4 | 0.9 | 0.9 |
| 900 rpm | 8. | 460 | 8197 | 6.2 | 803 | 738 | 775 | 57.4 | 2.0 | 1.3 |
| 100% load | 16. | 468 | 7508 | 6.1 | 830 | 770 | 810 | 61.3 | 2.9 | 1.5 |
|  | 20. | 434 | 7849 | 6.1 | 856 | 778 | 815 | 60.3 | 2.1 | 1.3 |
| Average |  | 454 | 7851 | 6.1 | 830 | 762 | 800 | 59.7 | 2.3 | 1.4 |
| 1500 rpm | 10. | 222 | 135 | 1.5 | 186 | 160 | 196 | 26.1 | 0.7 | 0.8 |
| 2% load | 15. | 232 | 88 | 1.5 | 196 | 167 | 198 | 26.3 | 1.1 | 1.0 |
|  | 21. | 246 | 112 | 1.5 | 192 | 153 | 188 | 25.9 | 0.9 | 1.0 |
| Average |  | 233 | 112 | 1.5 | 191 | 160 | 194 | 26.1 | 0.9 | 0.9 |
| 1500 rpm | 4. | 280 | 111 | 3.5 | 628 | 610 | 658 | 30.5 | 0.9 | 1.0 |
| 50% load | 9. | 230 | 85 | 3.4 | 630 | 573 | 623 | 28.5 | 1.6 | 1.2 |
|  | 18. | 250 | 94 | 3.4 | 600 | 540 | 587 | 27.7 | 0.8 | 0.9 |
| Average |  | 253 | 97 | 3.4 | 619 | 574 | 623 | 28.9 | 1.1 | 1.0 |
| 1500 rpm | 2. | 342 | 1886 | 6.2 | 1088 | 1030 | 1093 | 54.6 | 2.4 | 1.4 |
| 100% load | 5. | 340 | 1808 | 6.2 | 1114 | 1045 | 1083 | 52.5 | 2.0 | 1.3 |
|  | 14. | 352 | 1792 | 6.1 | 1193 | 1078 | 1140 | 54.8 | 2.9 | 1.5 |
| Average |  | 345 | 1829 | 6.2 | 1132 | 1051 | 1105 | 54.0 | 2.4 | 1.4 |
| Idle | 7. | 205 | 129 | 0.9 | 186 | 160 | 202 | 19.7 | 0.6 | 0.8 |
|  | 12. | 206 | 135 | 0.9 | 190 | 160 | 204 | 20.4 | 1.0 | 1.0 |
|  | 19. | 194 | 115 | 0.9 | 198 | 159 | 194 | 20.7 | 0.8 | 0.9 |
| Average |  | 202 | 126 | 0.9 | 191 | 160 | 200 | 20.3 | 0.8 | 0.9 |

## TABLE F-3. GASEOUS EMISSIONS SUMMARY

Engine: Detroit Diesel 6V-71
Date: August 21, 1975

Injectors: LSN 60
Dilution: 100:1

| | | | | | NDIR | CL | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 900 rpm | 5. | 142 | 151 | 1.1 | 150 | 138 | 170 | 16.4 | 1.3 | 1.1 |
| 2% load | 12. | 150 | 140 | 1.1 | 154 | 140 | 177 | 21.8 | 1.7 | 1.2 |
| | 20. | 148 | 143 | 1.1 | 170 | 142 | 175 | 10.1 | 0.8 | 0.9 |
| Average | | 147 | 145 | 1.1 | 158 | 140 | 174 | 16.1 | 1.3 | 1.1 |
| 900 rpm | 4. | 218 | 108 | 3.3 | 702 | 646 | 710 | 16.1 | 1.1 | 1.0 |
| 50% load | 14. | 239 | 94 | 3.3 | 713 | 643 | 712 | 25.0 | 1.5 | 1.2 |
| | 21. | 230 | 89 | 3.3 | 763 | 668 | 730 | 21.5 | 1.4 | 1.1 |
| Average | | 229 | 97 | 3.3 | 726 | 652 | 717 | 20.9 | 1.3 | 1.1 |
| 900 rpm | 1. | 392 | 8197 | 6.1 | 731 | 708 | 735 | 46.8 | 3.4 | 1.5 |
| 100% load | 8. | 444 | 8109 | 6.2 | 775 | 732 | 778 | 55.0 | 4.2 | 1.6 |
| | 18. | 432 | 7193 | 6.2 | 856 | 783 | 820 | 49.5 | 3.8 | 1.6 |
| Average | | 423 | 7833 | 6.2 | 787 | 741 | 778 | 50.4 | 3.8 | 1.6 |
| 1500 rpm | 6. | 173 | 127 | 1.5 | 158 | 156 | 190 | 20.5 | 1.6 | 1.2 |
| 2% load | 13. | 156 | 121 | 1.5 | 178 | 157 | 190 | 20.4 | 1.6 | 1.2 |
| | 19. | 163 | 116 | 1.5 | 186 | 162 | 198 | 19.6 | 1.6 | 1.2 |
| Average | | 164 | 121 | 1.5 | 174 | 158 | 193 | 20.2 | 1.6 | 1.2 |
| 1500 rpm | 7. | 257 | 94 | 3.5 | 635 | 593 | 645 | 20.9 | 1.4 | 1.1 |
| 50% load | 10. | 278 | 94 | 3.4 | 644 | 589 | 638 | 23.4 | 1.6 | 1.2 |
| | 15. | 257 | 91 | 3.4 | 630 | 575 | 623 | 23.2 | 1.6 | 1.2 |
| Average | | 264 | 93 | 3.4 | 636 | 586 | 635 | 22.5 | 1.5 | 1.2 |
| 1500 rpm | 2. | 332 | 1652 | 6.1 | 1120 | 1070 | 1125 | 47.3 | 4.1 | 1.6 |
| 100% load | 9. | 306 | 1730 | 6.2 | 1120 | 1043 | 1093 | 44.1 | 3.4 | 1.5 |
| | 17. | 324 | 1749 | 6.2 | 1176 | 1073 | 1133 | 39.6 | 3.1 | 1.5 |
| Average | | 321 | 1710 | 6.2 | 1139 | 1062 | 1117 | 43.7 | 3.5 | 1.5 |
| Idle | 3. | 146 | 108 | 0.9 | 172 | 170 | 202 | 14.2 | 1.2 | 1.1 |
| | 11. | 150 | 156 | 1.0 | 174 | 153 | 192 | 15.2 | 1.2 | 1.1 |
| | 16. | 152 | 113 | 1.0 | 176 | 156 | 201 | 16.9 | 1.3 | 1.1 |
| Average | | 149 | 126 | 1.0 | 174 | 160 | 198 | 15.4 | 1.2 | 1.1 |

## TABLE F-4. GASEOUS EMISSIONS SUMMARY

Engine: Detroit Diesel 6V-71
Date: August 26, 1975

Injectors: B60E
Dilution: 100:1

| | | | | | NDIR | CL | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 900 rpm 2% load | 2. | 104 | 194 | 1.1 | 72 | 70 | 93 | 19.3 | 2.3 | 1.4 |
| | 7. | 144 | 225 | 1.2 | 65 | 61 | 86 | 20.4 | 2.7 | 1.4 |
| | 12. | 111 | 202 | 1.1 | 77 | 67 | 89 | 19.4 | 2.3 | 1.4 |
| Average | | 120 | 207 | 1.1 | 71 | 66 | 89 | 19.7 | 2.4 | 1.4 |
| 900 rpm 50% load | 8. | 72 | 94 | 3.3 | 371 | 338 | 372 | 13.0 | 1.6 | 1.2 |
| | 17. | 84 | 85 | 3.3 | 403 | 371 | 405 | 10.0 | 0.9 | 1.0 |
| | 20. | 70 | 88 | 3.1 | 421 | 382 | 412 | 11.1 | 1.0 | 1.0 |
| Average | | 75 | 89 | 3.2 | 398 | 364 | 396 | 11.4 | 1.2 | 1.1 |
| 900 rpm 100% load | 14. | 232 | 4317 | 6.2 | 979 | 892 | 925 | 30.6 | 3.0 | 1.5 |
| | 16. | 212 | 3445 | 6.2 | 1054 | 947 | 977 | 24.8 | 2.1 | 1.3 |
| | 18. | 192 | 3101 | 5.6 | 1061 | 960 | 1002 | 24.4 | 1.6 | 1.2 |
| Average | | 212 | 3621 | 6.0 | 1031 | 933 | 968 | 26.6 | 2.2 | 1.3 |
| 1500 rpm 2% load | 4. | 124 | 252 | 1.5 | 66 | 62 | 88 | 20.6 | 2.7 | 1.4 |
| | 11. | 132 | 238 | 1.5 | 77 | 63 | 92 | 19.4 | 2.6 | 1.4 |
| | 19. | 123 | 216 | 1.5 | 76 | 74 | 100 | 22.5 | 2.5 | 1.4 |
| Average | | 126 | 235 | 1.5 | 73 | 66 | 93 | 20.8 | 2.6 | 1.4 |
| 1500 rpm 50% load | 3. | 104 | 81 | 3.4 | 297 | 278 | 310 | 18.1 | 1.6 | 1.2 |
| | 10. | 100 | 94 | 3.4 | 295 | 269 | 291 | 16.9 | 1.6 | 1.2 |
| | 15. | 96 | 78 | 3.4 | 302 | 280 | 309 | 13.2 | 1.3 | 1.1 |
| Average | | 100 | 84 | 3.4 | 298 | 276 | 303 | 16.1 | 1.5 | 1.2 |
| 1500 rpm 100% load | 1. | 126 | 1213 | 5.9 | 856 | 818 | 843 | 26.6 | 2.6 | 1.4 |
| | 5. | 140 | 1423 | 6.2 | 861 | 793 | 825 | 28.6 | 3.4 | 1.5 |
| | 9. | 140 | 1423 | 6.2 | 838 | 773 | 813 | 26.4 | 3.0 | 1.5 |
| Average | | 135 | 1353 | 6.1 | 852 | 795 | 827 | 27.2 | 3.0 | 1.5 |
| Idle | 6. | 158 | 139 | 0.9 | 103 | 96 | 113 | 23.6 | 2.1 | 1.3 |
| | 13. | 122 | 121 | 0.9 | 99 | 90 | 113 | 14.0 | 1.3 | 1.1 |
| | 21. | 116 | 126 | 1.0 | 89 | 90 | 113 | 18.4 | 1.4 | 1.1 |
| Average | | 132 | 129 | 0.9 | 97 | 92 | 113 | 18.7 | 1.6 | 1.2 |

## TABLE F-5. GASEOUS EMISSIONS SUMMARY

Engine: Detroit Diesel 6V-71
Date: August 28, 1975

Injectors: B60E
Dilution: 100:1

| | | | | | NDIR | CL | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 900 rpm | 1. | 138 | 202 | 1.0 | 74 | 68 | 90 | 22.6 | 2.6 | 1.4 |
| 2% load | 6. | 122 | 189 | 1.1 | 64 | 67 | 96 | 16.1 | 2.4 | 1.4 |
| | 13. | 106 | 181 | 1.2 | 82 | 73 | 99 | 12.2 | 2.1 | 1.3 |
| Average | | 122 | 191 | 1.1 | 73 | 69 | 95 | 17.0 | 2.4 | 1.4 |
| 900 rpm | 3. | 80 | 81 | 3.3 | 386 | 388 | 418 | 12.5 | 1.4 | 1.1 |
| 50% load | 11. | 74 | 89 | 3.4 | 434 | 393 | 426 | 8.1 | 1.4 | 1.1 |
| | 19. | 84 | 75 | 3.3 | 412 | 388 | 420 | 9.4 | 1.4 | 1.1 |
| Average | | 79 | 82 | 3.3 | 411 | 390 | 421 | 10.0 | 1.4 | 1.1 |
| 900 rpm | 9. | 166 | 3410 | 6.2 | 990 | 963 | 998 | 24.6 | 3.0 | 1.5 |
| 100% load | 15. | 252 | 3410 | 6.5 | 1083 | 1005 | 1033 | 24.4 | 2.6 | 1.4 |
| | 17. | 190 | 3410 | 6.5 | 1083 | 993 | 1028 | 25.7 | 2.7 | 1.4 |
| Average | | 203 | 3410 | 6.4 | 1052 | 987 | 1020 | 24.9 | 2.8 | 1.4 |
| 1500 rpm | 2. | 130 | 230 | 1.5 | 70 | 64 | 92 | 23.9 | 3.1 | 1.5 |
| 2% load | 10. | 122 | 202 | 1.5 | 76 | 70 | 100 | 14.1 | 2.4 | 1.4 |
| | 18. | 148 | 213 | 1.5 | 78 | 79 | 99 | 15.9 | 2.3 | 1.4 |
| Average | | 133 | 215 | 1.5 | 75 | 71 | 97 | 18.0 | 2.6 | 1.4 |
| 1500 rpm | 7. | 106 | 81 | 3.4 | 343 | 280 | 312 | 12.6 | 1.9 | 1.3 |
| 50% load | 14. | 78 | 86 | 3.6 | 336 | 303 | 330 | 8.8 | 1.6 | 1.2 |
| | 21. | 68 | 62 | 3.2 | 313 | 300 | 331 | 8.1 | 1.2 | 1.1 |
| Average | | 84 | 76 | 3.4 | 331 | 294 | 324 | 9.8 | 1.6 | 1.2 |
| 1500 rpm | 4. | 148 | 1183 | 6.0 | 874 | 859 | 894 | 22.4 | 3.4 | 1.5 |
| 100% load | 8. | 152 | 1198 | 6.1 | 840 | 840 | 885 | 19.7 | 2.7 | 1.4 |
| | 16. | 152 | 1163 | 6.4 | 934 | 850 | 895 | 23.4 | 3.0 | 1.5 |
| Average | | 151 | 1181 | 6.2 | 883 | 850 | 891 | 21.8 | 3.0 | 1.5 |
| Idle | 5. | 202 | 142 | 0.9 | 103 | 102 | 122 | 18.6 | 1.9 | 1.3 |
| | 12. | 137 | 129 | 0.9 | 105 | 91 | 119 | 15.6 | 1.5 | 1.2 |
| | 20. | 138 | 135 | 0.9 | 99 | 97 | 122 | 12.4 | 1.3 | 1.1 |
| Average | | 159 | 135 | 0.9 | 102 | 97 | 121 | 15.5 | 1.6 | 1.2 |

## TABLE F-6. COMPARISON OF GASEOUS EMISSIONS
Cummins NTC-290

| | | | | | | NDIR | CL | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Date | Conf.* | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/1 | LCO, µg/1 | TIA |
| 1400 rpm 2% load | 8/5/75 | C | 76 | 116 | 2.2 | 171 | 153 | 178 | 5.3 | 2.3 | 1.4 |
| | 8/7/75 | C | 79 | 104 | 2.2 | 157 | 156 | 184 | 10.1 | 2.1 | 1.4 |
| | Average | | 78 | 110 | 2.2 | 164 | 155 | 181 | 7.7 | 2.2 | 1.4 |
| | 8/12/75 | L | 90 | 133 | 2.1 | 118 | 103 | 118 | 6.2 | 2.2 | 1.3 |
| | 8/14/75 | L | 101 | 144 | 2.0 | 112 | 98 | 110 | 6.5 | 1.9 | 1.3 |
| | Average | | 96 | 139 | 2.1 | 115 | 101 | 114 | 6.4 | 2.1 | 1.3 |
| 1400 rpm 50% load | 8/5/75 | C | 63 | 143 | 6.2 | 888 | 849 | 900 | 4.6 | 2.1 | 1.3 |
| | 8/7/75 | C | 64 | 144 | 6.1 | 886 | 839 | 896 | 4.3 | 1.7 | 1.2 |
| | Average | | 64 | 144 | 6.2 | 887 | 844 | 898 | 4.5 | 1.9 | 1.3 |
| | 8/12/75 | L | 98 | 189 | 6.3 | 307 | 278 | 285 | 9.4 | 2.8 | 1.4 |
| | 8/14/75 | L | 87 | 162 | 6.2 | 320 | 297 | 303 | 7.7 | 2.0 | 1.3 |
| | Average | | 93 | 176 | 6.3 | 314 | 288 | 294 | 8.6 | 2.4 | 1.4 |
| 1400 rpm 100% load | 8/5/75 | C | 69 | 621 | 9.8 | 2059 | 2002 | 2118 | 3.8 | 2.6 | 1.4 |
| | 8/7/75 | C | 73 | 617 | 9.3 | 2078 | 2061 | 2195 | 4.8 | 1.9 | 1.2 |
| | Average | | 71 | 619 | 9.6 | 2069 | 2032 | 2157 | 4.3 | 2.3 | 1.3 |
| | 8/12/75 | L | 83 | 567 | 9.2 | 732 | 667 | 683 | 5.1 | 2.6 | 1.3 |
| | 8/14/75 | L | 88 | 451 | 8.9 | 702 | 688 | 705 | 4.7 | 2.1 | 1.3 |
| | Average | | 86 | 509 | 9.1 | 717 | 678 | 694 | 4.9 | 2.4 | 1.3 |
| 2100 rpm 2% load | 8/5/75 | C | 70 | 105 | 2.8 | 219 | 199 | 222 | 5.4 | 2.3 | 1.4 |
| | 8/7/75 | C | 73 | 101 | 2.8 | 222 | 190 | 214 | 5.4 | 1.7 | 1.2 |
| | Average | | 72 | 103 | 2.8 | 221 | 195 | 218 | 5.4 | 2.0 | 1.3 |
| | 8/12/75 | L | 88 | 115 | 2.8 | 139 | 122 | 138 | 7.4 | 2.1 | 1.3 |
| | 8/14/75 | L | 91 | 112 | 2.8 | 142 | 130 | 140 | 12.9 | 2.8 | 1.4 |
| | Average | | 90 | 114 | 2.8 | 140 | 126 | 139 | 10.2 | 2.5 | 1.4 |
| 2100 rpm 50% load | 8/5/75 | C | 62 | 97 | 5.3 | 726 | 657 | 695 | 4.3 | 2.1 | 1.3 |
| | 8/7/75 | C | 65 | 86 | 5.4 | 702 | 649 | 682 | 3.9 | 2.7 | 1.4 |
| | Average | | 64 | 92 | 5.4 | 714 | 653 | 689 | 4.1 | 2.4 | 1.4 |
| | 8/12/75 | L | 99 | 134 | 5.3 | 250 | 226 | 234 | 9.1 | 3.0 | 1.5 |
| | 8/14/75 | L | 90 | 112 | 5.3 | 260 | 230 | 247 | 8.2 | 2.2 | 1.3 |
| | Average | | 95 | 123 | 5.3 | 255 | 228 | 241 | 8.7 | 2.6 | 1.4 |
| 2100 rpm 100% load | 8/5/75 | C | 80 | 112 | 6.0 | 1875 | 1795 | 1923 | 5.1 | 3.1 | 1.5 |
| | 8/7/75 | C | 86 | 103 | 7.2 | 1827 | 1770 | 1890 | 4.9 | 1.9 | 1.3 |
| | Average | | 83 | 108 | 6.6 | 1851 | 1783 | 1907 | 5.0 | 2.5 | 1.4 |
| | 8/12/75 | L | 87 | 142 | 7.0 | 636 | 574 | 587 | 6.8 | 3.0 | 1.5 |
| | 8/14/75 | L | 88 | 148 | 7.0 | 702 | 628 | 645 | 6.7 | 4.7 | 1.6 |
| | Average | | 88 | 145 | 7.0 | 669 | 601 | 616 | 6.8 | 3.9 | 1.6 |
| Idle | 8/5/75 | C | 105 | 98 | 1.5 | 131 | 114 | 140 | 5.8 | 2.8 | 1.4 |
| | 8/7/75 | C | 93 | 83 | 1.5 | 134 | 107 | 143 | 5.3 | 1.5 | 1.2 |
| | Average | | 99 | 91 | 1.5 | 133 | 111 | 142 | 5.6 | 2.2 | 1.3 |
| | 8/12/75 | L | 144 | 125 | 1.5 | 89 | 78 | 92 | 9.5 | 2.9 | 1.4 |
| | 8/14/75 | L | 130 | 126 | 1.4 | 89 | 77 | 93 | 11.8 | 2.9 | 1.4 |
| | Average | | 137 | 126 | 1.5 | 89 | 78 | 93 | 10.7 | 2.9 | 1.4 |

## TABLE F-7. GASEOUS EMISSIONS SUMMARY

Engine: Cummins NTC-290 (Current)
Date: August 5, 1975

Timing: Standard
Dilution: 100:1

| | | | | | NDIR | CL | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 1400 rpm | 5. | 71 | 127 | 2.1 | 158 | 140 | 161 | 6.7 | 3.0 | 1.5 |
| 2% load | 10. | 77 | 108 | 2.2 | 190 | 159 | 182 | 4.6 | 1.6 | 1.2 |
| | 16. | 81 | 112 | 2.2 | 164 | 160 | 190 | 4.7 | 2.3 | 1.4 |
| Average | | 76 | 116 | 2.2 | 171 | 153 | 178 | 5.3 | 2.3 | 1.4 |
| 1400 rpm | 3. | 59 | 152 | 6.1 | 896 | 868 | 918 | 4.6 | 2.4 | 1.4 |
| 50% load | 14. | 65 | 148 | - | 884 | 830 | 880 | 3.8 | 2.3 | 1.4 |
| | 21. | 64 | 130 | 6.3 | 884 | 850 | 903 | 5.3 | 1.7 | 1.2 |
| Average | | 63 | 143 | 6.2 | 888 | 849 | 900 | 4.6 | 2.1 | 1.3 |
| 1400 rpm | 1. | 64 | 582 | 9.3 | 2030 | 2030 | 2150 | 2.9 | 1.7 | 1.2 |
| 100% load | 9. | 77 | 633 | 9.5 | 2160 | 1975 | 2108 | 5.0 | 3.2 | 1.5 |
| | 18. | 66 | 647 | 10.6 | 1986 | 2000 | 2095 | 3.5 | 3.0 | 1.5 |
| Average | | 69 | 621 | 9.8 | 2059 | 2002 | 2118 | 3.8 | 2.6 | 1.4 |
| 2100 rpm | 7. | 71 | 81 | 2.7 | 230 | 202 | 226 | 5.8 | 2.7 | 1.4 |
| 2% load | 13. | 64 | 121 | 2.8 | 218 | 194 | 216 | 5.4 | 1.8 | 1.3 |
| | 20. | 75 | 112 | 2.8 | 210 | 201 | 223 | 5.0 | 2.5 | 1.4 |
| Average | | 70 | 105 | 2.8 | 219 | 199 | 222 | 5.4 | 2.3 | 1.4 |
| 2100 rpm | 2. | 63 | 94 | 5.3 | 751 | 661 | 699 | 3.9 | 1.9 | 1.3 |
| 50% load | 8. | 57 | 104 | 5.4 | 704 | 642 | 673 | 5.1 | 2.6 | 1.4 |
| | 19. | 67 | 92 | 5.3 | 723 | 668 | 712 | 4.0 | 1.7 | 1.2 |
| Average | | 62 | 97 | 5.3 | 726 | 657 | 695 | 4.3 | 2.1 | 1.3 |
| 2100 rpm | 6. | 82 | 112 | 6.0 | 1824 | 1758 | 1868 | 5.8 | 3.2 | 1.5 |
| 100% load | 11. | 74 | 94 | - | 1880 | 1803 | 1933 | 4.5 | 3.2 | 1.5 |
| | 15. | 84 | 130 | - | 1922 | 1825 | 1968 | 5.0 | 3.0 | 1.5 |
| Average | | 80 | 112 | 6.0 | 1875 | 1795 | 1923 | 5.1 | 3.1 | 1.5 |
| Idle | 4. | 100 | 104 | 1.5 | 125 | 107 | 132 | 7.2 | 3.0 | 1.5 |
| | 12. | 99 | 81 | 1.6 | 150 | 128 | 155 | 4.5 | 2.6 | 1.4 |
| | 17. | 116 | 108 | 1.5 | 117 | 108 | 133 | 5.6 | 2.8 | 1.4 |
| Average | | 105 | 98 | 1.5 | 131 | 114 | 140 | 5.8 | 2.8 | 1.4 |

## TABLE F-8. GASEOUS EMISSIONS SUMMARY

Engine: Cummins NTC-290 (Current)
Date: August 7, 1975

Timing: Standard
Dilution: 100:1

|  |  |  |  |  | NDIR | CL |  | DOAS Results |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 1400 rpm | 6. | 78 | 117 | 2.2 | 154 | 146 | 172 | 4.3 | 1.2 | 1.0 |
| 2% load | 12. | 83 | 108 | 2.1 | 175 | 160 | 187 | 22.0 | 3.3 | 1.5 |
|  | 17. | 76 | 88 | 2.2 | 142 | 163 | 192 | 4.1 | 1.8 | 1.3 |
| Average |  | 79 | 104 | 2.2 | 157 | 156 | 184 | 10.1 | 2.1 | 1.4 |
| 1400 rpm | 1. | 65 | 135 | 6.1 | 809 | 825 | 873 | 2.8 | 1.0 | 1.0 |
| 50% load | 8. | 66 | 162 | 6.2 | 995 | 880 | 963 | 4.0 | 1.8 | 1.3 |
|  | 19. | 62 | 135 | 6.1 | 854 | 913 | 853 | 6.2 | 2.3 | 1.4 |
| Average |  | 64 | 144 | 6.1 | 886 | 839 | 896 | 4.3 | 1.7 | 1.2 |
| 1400 rpm | 4. | 76 | 576 | 9.3 | 2145 | 2060 | 2243 | 7.2 | 2.2 | 1.3 |
| 100% load | 13. | 72 | 641 | 9.4 | 2073 | 2048 | 2143 | 3.4 | 1.4 | 1.1 |
|  | 21. | 71 | 633 | 9.3 | 2015 | 2075 | 2200 | 3.9 | 2.1 | 1.3 |
| Average |  | 73 | 617 | 9.3 | 2078 | 2061 | 2195 | 4.8 | 1.9 | 1.2 |
| 2100 rpm | 2. | 75 | 94 | 2.8 | 218 | 182 | 207 | 4.8 | 1.5 | 1.2 |
| 2% load | 9. | 72 | - | 2.9 | 235 | 192 | 216 | 6.5 | 1.7 | 1.2 |
|  | 15. | 72 | 108 | 2.7 | 212 | 197 | 219 | 4.8 | 1.8 | 1.3 |
| Average |  | 73 | 101 | 2.8 | 222 | 190 | 214 | 5.4 | 1.7 | 1.2 |
| 2100 rpm | 3. | 67 | 77 | 5.3 | 685 | 622 | 658 | 4.4 | 1.4 | 1.1 |
| 50% load | 14. | 67 | 90 | 5.4 | 713 | 663 | 717 | 4.0 | 4.5 | 1.7 |
|  | 20. | 62 | 90 | 5.4 | 709 | 642 | 670 | 3.2 | 2.1 | 1.3 |
| Average |  | 65 | 86 | 5.4 | 702 | 649 | 682 | 3.9 | 2.7 | 1.4 |
| 2100 rpm | 7. | 95 | 121 | 7.2 | 1863 | 1770 | 1900 | 4.4 | 1.7 | 1.2 |
| 100% load | 11. | 88 | 94 | 7.2 | 1762 | 1770 | 1875 | 5.8 | 2.0 | 1.3 |
|  | 16. | 76 | 94 | 7.1 | 1855 | 1770 | 1895 | 4.6 | 2.0 | 1.3 |
| Average |  | 86 | 103 | 7.2 | 1827 | 1770 | 1890 | 4.9 | 1.9 | 1.3 |
| Idle | 5. | 90 | 90 | 1.5 | 150 | 106 | 149 | 4.3 | 1.3 | 1.1 |
|  | 10. | 90 | 81 | 1.5 | 123 | 103 | 143 | 6.5 | 1.4 | 1.1 |
|  | 18. | 98 | 77 | 1.5 | 128 | 111 | 137 | 5.0 | 1.7 | 1.2 |
| Average |  | 93 | 83 | 1.5 | 134 | 107 | 143 | 5.3 | 1.5 | 1.2 |

## TABLE F-9. GASEOUS EMISSIONS SUMMARY

Engine: Cummins NTC-290 (Low)
Date: August 12, 1975

Timing: Variable
Dilution: 100:1

| | | | | | NDIR | CL | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 1400 rpm | 2. | 87 | 130 | 2.1 | 124 | 106 | 122 | 6.2 | 3.0 | 1.5 |
| 2% load | 7. | 88 | 135 | 2.1 | 124 | 105 | 118 | 6.0 | 2.5 | 1.4 |
| | 14. | 96 | 135 | 2.0 | 107 | 98 | 113 | 6.4 | 1.1 | 1.0 |
| Average | | 90 | 133 | 2.1 | 118 | 103 | 118 | 6.2 | 2.2 | 1.3 |
| 1400 rpm | 10. | 103 | 202 | 6.4 | 316 | 280 | 292 | 9.4 | 2.5 | 1.4 |
| 50% load | 15. | 96 | 189 | 6.2 | 288 | 275 | 273 | 10.8 | 3.3 | 1.5 |
| | 20. | 96 | 175 | 6.3 | 316 | 278 | 289 | 8.1 | 2.5 | 1.4 |
| Average | | 98 | 189 | 6.3 | 307 | 278 | 285 | 9.4 | 2.8 | 1.4 |
| 1400 rpm | 6. | 85 | 492 | 9.1 | 731 | 660 | 672 | 5.1 | 3.5 | 1.5 |
| 100% load | 11. | 76 | 647 | 9.2 | 749 | 670 | 687 | 5.0 | 1.4 | 1.1 |
| | 18. | 88 | 562 | 9.3 | 716 | 672 | 690 | 5.1 | 2.8 | 1.4 |
| Average | | 83 | 567 | 9.2 | 732 | 667 | 683 | 5.1 | 2.6 | 1.3 |
| 2100 rpm | 5. | 90 | 108 | 2.8 | 146 | 121 | 139 | 7.9 | 3.6 | 1.6 |
| 2% load | 9. | 88 | 117 | 2.8 | 127 | 117 | 135 | 8.2 | 1.0 | 1.0 |
| | 19. | 86 | 120 | 2.8 | 145 | 127 | 140 | 6.2 | 1.8 | 1.3 |
| Average | | 88 | 115 | 2.8 | 139 | 122 | 138 | 7.4 | 2.1 | 1.3 |
| 2100 rpm | 4. | 104 | 138 | 5.2 | 259 | 226 | 234 | 8.9 | 3.9 | 1.6 |
| 50% load | 13. | 98 | 117 | 5.4 | 229 | 224 | 233 | 9.1 | 1.8 | 1.3 |
| | 21. | 96 | 148 | 5.4 | 263 | 227 | 234 | 9.3 | 3.3 | 1.5 |
| Average | | 99 | 134 | 5.3 | 250 | 226 | 234 | 9.1 | 3.0 | 1.5 |
| 2100 rpm | 1. | 80 | 130 | 7.0 | 616 | 556 | 570 | 6.2 | 3.1 | 1.5 |
| 100% load | 8. | 90 | 165 | 7.0 | 654 | 570 | 580 | 6.2 | 3.4 | 1.5 |
| | 16. | 91 | 130 | 7.0 | 639 | 595 | 610 | 7.9 | 2.4 | 1.4 |
| Average | | 87 | 142 | 7.0 | 636 | 574 | 587 | 6.8 | 3.0 | 1.5 |
| Idle | 3. | 146 | 135 | 1.4 | 77 | 65 | 83 | 8.7 | 3.2 | 1.5 |
| | 12. | 147 | 120 | 1.5 | 93 | 82 | 93 | 10.6 | 2.0 | 1.3 |
| | 17. | 140 | 121 | 1.5 | 97 | 88 | 100 | 9.1 | 3.4 | 1.5 |
| Average | | 144 | 125 | 1.5 | 89 | 78 | 92 | 9.5 | 2.9 | 1.4 |

## TABLE F-10. GASEOUS EMISSIONS SUMMARY

Engine: Cummins NTC-290 (Low)
Date: August 14, 1975

Timing: Variable
Dilution: 100:1

| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NDIR NO, ppm | CL NO, ppm | CL $NO_x$, ppm | DOAS Results LCA, μg/l | DOAS Results LCO, μg/l | DOAS Results TIA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1400 rpm<br>2% load | 3. | 108 | 148 | 2.0 | 122 | 105 | 115 | 5.7 | 1.8 | 1.3 |
| | 9. | 100 | 108 | 2.0 | 111 | 95 | 100 | 6.8 | 2.6 | 1.4 |
| | 15. | 96 | 175 | 2.0 | 103 | 95 | 115 | 7.1 | 1.3 | 1.1 |
| Average | | 101 | 144 | 2.0 | 112 | 98 | 110 | 6.5 | 1.9 | 1.3 |
| 1400 rpm<br>50% load | 7. | 72 | 175 | 6.2 | 347 | 305 | 310 | 6.0 | 2.1 | 1.3 |
| | 13. | 92 | 121 | 6.2 | 326 | 295 | 305 | 7.4 | 1.3 | 1.1 |
| | 19. | 98 | 189 | 6.2 | 288 | 290 | 295 | 9.6 | 2.5 | 1.4 |
| Average | | 87 | 162 | 6.2 | 320 | 297 | 303 | 7.7 | 2.0 | 1.3 |
| 1400 rpm<br>100% load | 2. | 104 | 451 | 8.9 | 736 | 700 | 710 | 3.7 | 1.4 | 1.1 |
| | 10. | 88 | 409 | 8.9 | 745 | 665 | 690 | 5.2 | 3.0 | 1.5 |
| | 21. | 72 | 492 | 8.8 | 625 | 690 | 715 | 5.1 | 1.8 | 1.3 |
| Average | | 88 | 451 | 8.9 | 702 | 688 | 705 | 4.7 | 2.1 | 1.3 |
| 2100 rpm<br>2% load | 11. | 92 | 54 | 2.8 | 146 | 125 | 135 | 14.5 | 4.0 | 1.6 |
| | 17. | 88 | 135 | 2.8 | 150 | 135 | 145 | 16.9 | 3.1 | 1.5 |
| | 20. | 92 | 148 | 2.8 | 130 | 130 | 140 | 7.3 | 1.4 | 1.1 |
| Average | | 91 | 112 | 2.8 | 142 | 130 | 140 | 12.9 | 2.8 | 1.4 |
| 2100 rpm<br>50% load | 1. | 90 | 135 | 5.2 | 259 | 225 | 245 | 7.9 | 2.0 | 1.3 |
| | 8. | 88 | 108 | 5.3 | 267 | 235 | 250 | 8.0 | 3.2 | 1.5 |
| | 12. | 92 | 94 | 5.3 | 255 | 230 | 245 | 8.7 | 1.4 | 1.1 |
| Average | | 90 | 112 | 5.3 | 260 | 230 | 247 | 8.2 | 2.2 | 1.3 |
| 2100 rpm<br>100% load | 4. | 88 | 135 | 7.0 | 697 | 630 | 645 | 6.7 | 2.6 | 1.4 |
| | 6. | 88 | 135 | 7.1 | 716 | 630 | 650 | 4.8 | 9.2 | 2.0 |
| | 16. | 88 | 175 | 7.0 | 692 | 625 | 640 | 8.5 | 2.2 | 1.3 |
| Average | | 88 | 148 | 7.0 | 702 | 628 | 645 | 6.7 | 4.7 | 1.6 |
| Idle | 5. | 136 | 135 | 1.5 | 107 | 85 | 100 | 15.8 | 4.9 | 1.7 |
| | 14. | 124 | 81 | 1.4 | 84 | 75 | 90 | 9.7 | 1.8 | 1.3 |
| | 18. | 130 | 162 | 1.4 | 76 | 70 | 90 | 9.9 | 2.[illegible] | 1.3 |
| Average | | 130 | 126 | 1.4 | 89 | 77 | 93 | 11.8 | 2.9 | 1.4 |

## TABLE F-11. SUMMARY OF GASEOUS EMISSIONS MEASUREMENTS
### Detroit Diesel 8V-71TA

| | | | | | NDIR | CL | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Date | HC, ppm C | CO, ppm | CO₂, % | NO, ppm | NO, ppm | NOₓ, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 1400 rpm 2% load | 1/12/76 | - | - | - | - | - | - | 10.0 | 5.7 | 1.8 |
| | 1/14/76 | 101 | 118 | 1.6 | 125 | 112 | 135 | 8.7 | 4.7 | 1.7 |
| | 1/16/76 | - | 127 | 1.5 | 110 | 103 | 135 | - | - | - |
| | Average | 101 | 123 | 1.6 | 118 | 108 | 135 | 9.4 | 5.2 | 1.8 |
| 1400 rpm 50% load | 1/12/76 | - | - | - | - | - | - | 10.5 | 4.7 | 1.7 |
| | 1/14/76 | 89 | 96 | 4.5 | 522 | 512 | 536 | 9.3 | 4.1 | 1.6 |
| | 1/16/76 | - | 89 | 4.1 | 531 | 510 | 534 | - | - | - |
| | Average | 89 | 93 | 4.3 | 527 | 511 | 535 | 9.9 | 4.4 | 1.7 |
| 1400 rpm 100% load | 1/12/76 | - | - | - | - | - | - | 9.0 | 6.5 | 1.8 |
| | 1/14/76 | 100 | 1049 | 6.8 | 1146 | 1034 | 1035 | 8.8 | 5.1 | 1.7 |
| | 1/16/76 | - | 1214 | 6.0 | 1040 | 1005 | 1055 | - | - | - |
| | Average | 100 | 1132 | 6.4 | 1093 | 1020 | 1045 | 8.9 | 5.8 | 1.8 |
| 2100 rpm 2% load | 1/12/76 | - | - | - | - | - | - | 11.6 | 5.9 | 1.7 |
| | 1/14/76 | 92 | 78 | 2.2 | 127 | 124 | 151 | 11.2 | 4.9 | 1.7 |
| | 1/16/76 | - | 89 | 2.0 | 117 | 122 | 146 | - | - | - |
| | Average | 92 | 84 | 2.1 | 122 | 123 | 149 | 11.4 | 5.4 | 1.7 |
| 2100 rpm 50% load | 1/12/76 | - | - | - | - | - | - | 11.5 | 5.2 | 1.7 |
| | 1/14/76 | 111 | 68 | 4.1 | 399 | 379 | 414 | 11.2 | 4.7 | 1.7 |
| | 1/16/76 | - | 84 | 3.6 | 426 | 408 | 460 | - | - | - |
| | Average | 111 | 76 | 3.9 | 413 | 394 | 437 | 11.4 | 5.0 | 1.7 |
| 2100 rpm 100% load | 1/12/76 | - | - | - | - | - | - | 10.2 | 5.9 | 1.8 |
| | 1/14/76 | 85 | 87 | 5.5 | 1071 | 959 | 1000 | 9.7 | 5.1 | 1.7 |
| | 1/16/76 | - | 89 | 5.2 | 948 | 929 | 975 | - | - | - |
| | Average | 85 | 88 | 5.4 | 1010 | 944 | 988 | 10.0 | 5.5 | 1.8 |
| Idle | 1/12/76 | - | - | - | - | - | - | 9.1 | 5.3 | 1.7 |
| | 1/14/76 | 141 | 91 | 1.1 | 185 | 169 | 189 | 8.6 | 4.6 | 1.7 |
| | 1/16/76 | - | 82 | 1.0 | 175 | 183 | 203 | - | - | - |
| | | 141 | 87 | 1.1 | 180 | 176 | 196 | 8.9 | 5.0 | 1.7 |

## TABLE F-12. GASEOUS EMISSIONS SUMMARY

Engine: Detroit Diesel 8V-71 TA

Date: January 14, 1976

|  |  |  |  |  | NDIR | CL |  | DOAS Results |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Run No. | HC, ppm C | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 1400 rpm | 6. | 104 | 131 | 1.3 | 126 | 115 | 133 | 9.0 | 4.9 | 1.7 |
| 2% load | 12. | 92 | 91 | 1.5 | 122 | 102 | 130 | 8.6 | 4.6 | 1.7 |
|  | 17. | 107 | 132 | 1.9 | 126 | 120 | 143 | 8.6 | 4.7 | 1.7 |
| Average |  | 101 | 118 | 1.6 | 125 | 112 | 135 | 8.7 | 4.7 | 1.7 |
| 1400 rpm | 1. | 110 | 105 | 3.9 | 525 | 496 | 518 | 8.4 | 3.4 | 1.6 |
| 50% load | 8. | 48 | 78 | 4.0 | 487 | 510 | 530 | 10.1 | 5.0 | 1.7 |
|  | 19. | 108 | 105 | 5.5 | 555 | 530 | 560 | 9.3 | 4.0 | 1.6 |
| Average |  | 89 | 96 | 4.5 | 522 | 512 | 536 | 9.3 | 4.1 | 1.6 |
| 1400 rpm | 4. | 104 | 1190 | 6.1 | 1131 | 1027 | 1055 | 12.8 | 7.2 | 1.9 |
| 100% load | 13. | 92 | 1015 | 6.6 | 1148 | 975 | 1050 | 7.3 | 4.7 | 1.7 |
|  | 21. | 104 | 942 | 7.6 | 1159 | 1100 | 1000 | 6.4 | 3.3 | 1.5 |
| Average |  | 100 | 1049 | 6.8 | 1146 | 1034 | 1035 | 8.8 | 5.1 | 1.7 |
| 2100 rpm | 2. | 126 | 78 | 2.0 | 122 | 117 | 143 | 9.1 | 3.8 | 1.6 |
| 2% load | 9. | 61 | 78 | 2.0 | 122 | 125 | 150 | 13.1 | 5.9 | 1.8 |
|  | 15. | 88 | 78 | 2.5 | 138 | 130 | 160 | 11.4 | 5.0 | 1.7 |
| Average |  | 92 | 78 | 2.2 | 127 | 124 | 151 | 11.2 | 4.9 | 1.7 |
| 2100 rpm | 3. | 142 | 60 | 3.5 | 377 | 370 | 402 | 13.5 | 5.7 | 1.8 |
| 50% load | 14. | 86 | 65 | 4.4 | 403 | 378 | 410 | 10.4 | 4.4 | 1.6 |
|  | 20. | 104 | 78 | 4.5 | 416 | 390 | 430 | 9.7 | 4.0 | 1.6 |
| Average |  | 111 | 68 | 4.1 | 399 | 379 | 414 | 11.2 | 4.7 | 1.7 |
| 2100 rpm | 7. | 80 | 91 | 3.9 | 1093 | 930 | 985 | 10.7 | 5.6 | 1.8 |
| 100% load | 11. | 95 | 78 | 5.4 | 1050 | 940 | 990 | 10.3 | 5.3 | 1.7 |
|  | 16. | 80 | 91 | 7.1 | 1071 | 1006 | 1025 | 8.1 | 4.4 | 1.7 |
| Average |  | 85 | 87 | 5.5 | 1071 | 959 | 1000 | 9.7 | 5.1 | 1.7 |
| Idle | 5. | 122 | 80 | 1.0 | 190 | 172 | 196 | 8.5 | 4.5 | 1.7 |
|  | 10. | 186 | 80 | 1.0 | 174 | 160 | 182 | 9.3 | 5.1 | 1.7 |
|  | 18. | 116 | 113 | 1.3 | 190 | 175 | 190 | 8.0 | 4.1 | 1.6 |
| Average |  | 141 | 91 | 1.1 | 185 | 169 | 189 | 8.6 | 4.6 | 1.7 |

## TABLE F-13. GASEOUS EMISSIONS SUMMARY

Engine: Detroit Diesel 8V-71TA

Date: January 16, 1976

|  |  |  |  | NDIR | CL |  | DOAS Results* |  |  |
|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Run No. | CO, ppm | $CO_2$, % | NO, ppm | NO, ppm | $NO_x$, ppm | LCA, µg/l | LCO, µg/l | TIA |
| 1400 rpm | 1. | 144 | 1.5 | 107 | 93 | 127 | 10.5 | 6.0 | 1.8 |
| 2% load | 9. | 126 | 1.5 | 115 | 107 | 139 | 9.3 | 5.1 | 1.7 |
|  | 16. | 111 | 1.5 | 109 | 109 | 140 | 10.3 | 6.1 | 1.8 |
| Average |  | 127 | 1.5 | 110 | 103 | 135 | 10.0 | 5.7 | 1.8 |
| 1400 rpm | 6. | 88 | 3.9 | 505 | 497 | 528 | 9.5 | 4.8 | 1.7 |
| 50% load | 13. | 100 | 4.4 | 537 | 520 | 543 | 10.9 | 4.9 | 1.7 |
|  | 19. | 78 | 3.9 | 551 | 513 | 530 | 11.1 | 4.5 | 1.7 |
| Average |  | 89 | 4.1 | 531 | 510 | 534 | 10.5 | 4.7 | 1.7 |
| 1400 rpm | 4. | 1219 | 5.8 | 950 | 958 | 1023 | 11.0 | 8.2 | 1.9 |
| 100% load | 10. | 1205 | 6.1 | 1054 | 1028 | 1068 | 9.4 | 6.7 | 1.8 |
|  | 17. | 1219 | 6.2 | 1115 | 1030 | 1075 | 6.5 | 4.4 | 1.7 |
| Average |  | 1214 | 6.0 | 1040 | 1005 | 1055 | 9.0 | 6.4 | 1.8 |
| 2100 rpm | 5. | 72 | 1.9 | 109 | 122 | 142 | 11.3 | 6.4 | 1.7 |
| 2% load | 11. | 85 | 2.0 | 115 | 123 | 147 | 12.2 | 5.9 | 1.8 |
|  | 14. | 111 | 2.1 | 126 | 122 | 148 | 11.5 | 5.4 | 1.7 |
| Average |  | 89 | 2.0 | 117 | 122 | 146 | 11.7 | 5.9 | 1.7 |
| 2100 rpm | 8. | 60 | 3.6 | 412 | 402 | 493 | 9.5 | 4.8 | 1.7 |
| 50% load | 15. | 109 | 4.0 | 430 | 408 | 439 | 15.0 | 6.6 | 1.8 |
|  | 21. | 84 | 3.3 | 436 | 413 | 448 | 10.0 | 4.3 | 1.6 |
| Average |  | 84 | 3.6 | 426 | 408 | 460 | 11.5 | 5.2 | 1.7 |
| 2100 rpm | 2. | 105 | 5.5 | 852 | 905 | 952 | 12.1 | 6.4 | 1.8 |
| 100% load | 7. | 70 | 5.0 | 922 | 923 | 972 | 8.7 | 4.8 | 1.7 |
|  | 20. | 91 | 5.0 | 1071 | 960 | 1002 | 9.7 | 6.4 | 1.8 |
| Average |  | 89 | 5.2 | 948 | 929 | 975 | 10.2 | 5.9 | 1.8 |
| Idle | 3. | 84 | 1.0 | 172 | 190 | 207 | 10.2 | 6.3 | 1.8 |
|  | 12. | 91 | 1.1 | 172 | 177 | 200 | 8.0 | 4.9 | 1.7 |
|  | 18. | 72 | 1.0 | 180 | 183 | 203 | 9.2 | 4.8 | 1.7 |
| Average |  | 82 | 1.0 | 175 | 183 | 203 | 9.1 | 5.3 | 1.7 |

*Run January 12, 1976

# APPENDIX G

# COMPUTER REDUCED 1975 FTP, SET AND FET GASEOUS AND FUEL ECONOMY DATA FOR FIVE LD DIESEL VEHICLES

## TABLE G-1.HC, CO, $NO_x$ AND FUEL RESULTS
## MERCEDES 220D COMPREX

| | | Emission Rate, g/km | | | Fuel Cons. | Fuel Econ. |
|---|---|---|---|---|---|---|
| Test | Date | HC | CO | NOx | 1/100 km | mpg |
| 1975 FTP | 11-21-75 | 0.11 | 0.85 | 0.69 | 9.58 | 24.55 |
| | 11-35-75 | 0.09 | 0.83 | 0.64 | 9.28 | 25.34 |
| | 11-25-75 | 0.12 | 0.75 | 0.62 | 8.44 | 27.87 |
| | Average | 0.11 | 0.81 | 0.65 | 9.10 | 25.92 |
| FTP Cold | 11-31-75 | 0.14 | 0.93 | 0.72 | 10.20 | 23.06 |
| | 11-24-75 | 0.10 | 0.85 | 0.66 | 9.64 | 24.40 |
| | 11-25-75 | 0.12 | 0.75 | 0.65 | 8.78 | 26.79 |
| | Average | 0.13 | 0.84 | 0.68 | 9.54 | 24.75 |
| FTP Hot | 11-21-75 | 0.11 | 0.76 | 0.65 | 8.88 | 26.49 |
| | 11-24-75 | 0.08 | 0.79 | 0.62 | 8.86 | 26.55 |
| | 11-25-75 | 0.11 | 0.72 | 0.59 | 8.21 | 28.65 |
| | Average | 0.11 | 0.76 | 0.65 | 9.10 | 27.23 |
| FET | 11-21-75 | 0.09 | 0.48 | 0.60 | 7.30 | 32.22 |
| | 11-24-75 | 0.06 | 0.50 | 0.53 | 7.03 | 33.46 |
| | 11-25-75 | 0.08 | 0.47 | 0.57 | 6.77 | 34.74 |
| | Average | 0.08 | 0.48 | 0.56 | 7.03 | 33.47 |
| SET | 11-21-75 | 0.09 | 0.57 | 0.60 | 7.72 | 30.47 |
| | 11-24-75 | 0.06 | 0.57 | 0.56 | 7.63 | 30.83 |
| | 11-25-75 | 0.04 | 0.52 | 0.56 | 7.12 | 33.03 |
| | Average | 0.06 | 0.55 | 0.57 | 7.49 | 31.44 |

TABLE G-2. VEHICLE EMISSION RESULTS - 1975 FTP

```
                      1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 1       DATE 11/21/75                    MFGR. CODE   COMPREX           YR. 1975
VEHICLE MODEL  MERCEDES 220D LA        ENGINE    2.20 LITRE 4 CYL.      TEST WT.  1587  KG             ROAD LOAD    8.4 KW
TEST TYPE  -4 COLD CONT.HC             COMMENTS  3 BAG

BAROMETER 748.54 MM OF HG.                                          WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.    21.1 DEG. C                                        ABS. HUMIDITY   5.8 MILLIGRAMS/KG
REL. HUMIDITY      37 PCT.
EXHAUST EMISSIONS

                                                                    BLOWER INLET PRESS., G1 254.0 MM. H20
     BLOWER DIF. PRESS., G2, 304.8 MM. H20                          BLOWER INLET TEMP.    43 DEG. C

     BAG RESULTS
     BAG NO.                                      1              2              3
     BLOWER REVOLUTIONS                        7511          12952           7597
     HC    SAMPLE  METER READING/SCALE        11.7/3          5.4/3          5.8/3
     HC    SAMPLE  PPM                           47             22             23
     HC    BACKGRD METER READING/SCALE         3.0/3          3.5/3          2.0/3
     HC    BACKGRD PPM                           12             14              8
     CO    SAMPLE  METER READING/SCALE        49.8/*         26.5/*         35.6/*
     CO    SAMPLE  PPM                           93             50             67
     CO    BACKGRD METER READING/SCALE          .4/*           .8/*           .1/*
     CO    BACKGRD PPM                            1              2              0
     CO2   SAMPLE  METER READING/SCALE        56.1/2         35.2/2         45.3/2
     CO2   SAMPLE  PERCENT                     1.65            .99           1.30
     CO2   BACKGRD METER READING/SCALE         2.9/2          3.0/2          2.7/2
     CO2   BACKGRD PERCENT                      .08            .08            .07
     NOX   SAMPLE  METER READING/SCALE        48.0/2         28.2/2         39.4/2
     NOX   SAMPLE  PPM                         48.0           28.2           39.4
     NOX   BACKGRD METER READING/SCALE         1.0/2          1.0/2          1.2/2
     NOX   BACKGRD PPM                          1.0            1.0            1.2

     HC    CONCENTRATION PPM                     36              9             16
     CO    CONCENTRATION PPM                     89             47             64
     CO2   CONCENTRATION PCT                   1.59            .92           1.24
     NOX   CONCENTRATION PPM                   47.1           27.3           38.3
     HC    MASS GRAMS                          1.18            .49            .52
     CO    MASS GRAMS                          5.82           5.35           4.28
     CO2   MASS GRAMS                       1644.62        1641.08        1299.77
     NOX   MASS GRAMS                          4.37           4.37           3.60

     WEIGHTED MASS HC        .11 GRAMS/KILOMETRE
     WEIGHTED MASS CO        .85 GRAMS/KILOMETRE
     WEIGHTED MASS CO2    255.49 GRAMS/KILOMETRE
     WEIGHTED MASS NOX       .63 GRAMS/KILOMETRE

    CARBON BALANCE FUEL CONSUMPTION =  9.58 LITRES PER HUNDRED KILOMETRES
    TOTAL CVS FLOW =    210.8 STD. CU. METRES
```

```
                        TABLE G-3.             VEHICLE EMISSION RESULTS - 1975 FTP
                                1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 2        DATE 11/24/75                  MFGR. CODE  COMPREX          YR. 1975
VEHICLE MODEL  MERCEDES 220D  L         ENGINE   2.20 LITRE 4 CYL.     TEST WT.  1587  KG           ROAD LOAD   8.4 KW
TEST TYPE  A-4 COLD CONT.HC             COMMENTS  3 BAG

BAROMETER 749.55 MM OF HG.                                          WET BULB TEMP  11.7 DEG. C
DRY BULB TEMP.    21.1 DEG. C                                        ABS. HUMIDITY   4.6 MILLIGRAMS/KG
REL. HUMIDITY      30 PCT.
EXHAUST EMISSIONS
                                                                    BLOWER INLET PRESS., G1 248.9 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                           BLOWER INLET TEMP.    44 DEG. C

    BAG RESULTS
    BAG NO.                                     1              2              3
    BLOWER REVOLUTIONS                        7517           12907          7522
    HC    SAMPLE  METER READING/SCALE          7.5/3          4.7/3          7.1/3
    HC    SAMPLE   PPM                         30             19             29
    HC    BACKGRD METER READING/SCALE          2.5/3          2.5/3          4.5/3
    HC    BACKGRD PPM                          10             10             18
    CO    SAMPLE   METER READING/SCALE        41.3/*         27.6/*         36.4/*
    CO    SAMPLE   PPM                         78             52             69
    CO    BACKGRD METER READING/SCALE          1.5/*          1.1/*           .5/*
    CO    BACKGRD PPM                           3              2              1
    CO2   SAMPLE   METER READING/SCALE        53.3/2         33.6/2         46.7/2
    CO2   SAMPLE   PERCENT                    1.56            .94           1.35
    CO2   BACKGRD METER READING/SCALE          3.1/2          2.5/2          2.5/2
    CO2   BACKGRD PERCENT                      .08            .07            .07
    NOX   SAMPLE   METER READING/SCALE        44.2/2         27.3/2         40.5/2
    NOX   SAMPLE   PPM                        44.2           27.3           40.5
    NOX   BACKGRD METER READING/SCALE          1.0/2           .9/2          1.2/2
    NOX   BACKGRD PPM                          1.0             .9            1.2

    HC    CONCENTRATION PPM                    21              9             12
    CO    CONCENTRATION PPM                    72             49             65
    CO2   CONCENTRATION PCT                   1.49            .88           1.29
    NOX   CONCENTRATION PPM                   43.3           26.5           39.4
    HC    MASS GRAMS                           .69            .53            .40
    CO    MASS GRAMS                          4.73           5.50           4.29
    CO2   MASS GRAMS                       1541.21        1567.23        1335.10
    NOX   MASS GRAMS                          3.89           4.08           3.54

    WEIGHTED MASS HC        .04 GRAMS/KILOMETRE
    WEIGHTED MASS CO        .83 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    247.85 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .64 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  9.28 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   209.5 STD. CU. METRES
```

```
                    TABLE G-4.            VEHICLE EMISSION RESULTS - 1975 FTP
                           1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 3        DATE 11/25/75                    MFGR. CODE   COMPREX            YR. 1975
VEHICLE MODEL  MERCEDES 220D LA         ENGINE   2.20 LITRE 4 CYL.       TEST WT.  1587 KG               ROAD LOAD   8.4 KW
TEST TYPE  -4 COLD CONT,HC              COMMENTS  3 BAG

BAROMETER 740.42 MM OF HG.                                               WET BULB TEMP  13.3 DEG. C
DRY BULB TEMP.    20.6 DEG. C                                             ABS. HUMIDITY   6.7 MILLIGRAMS/KG
REL. HUMIDITY      43 PCT.
EXHAUST EMISSIONS

                                                                         BLOWER INLET PRESS., G1 298.4 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                                BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                     1              2              3
    BLOWER REVOLUTIONS                        7520          12917           7511
    HC   SAMPLE  MET R READING/SCALE          12.0/2         11.4/2         11.1/2
    HC   SAMPLE  PPM                            24             23             22
    HC   BACKGRD METER READING/SCALE           4.0/2          3.5/2          4.0/2
    HC   BACKGRD PPM                             8              7              8
    CO   SAMPLE  METER READING/SCALE          35.7/*         29.4/*         34.1/*
    CO   SAMPLE  PPM                            67             46             64
    CO   BACKGRD METER READING/SCALE           .4/*           .3/*           .5/*
    CO   BACKGRD PPM                             1              1              1
    CO2  SAMPLE  METER READING/SCALE          47.7/2         31.2/2         41.9/2
    CO2  SAMPLE  PERCENT                      1.38            .87           1.20
    CO2  BACKGRD METER READING/SCALE           2.1/2          1.7/2          2.1/2
    CO2  BACKGRD PERCENT                       .06            .04            .06
    NOX  SAMPLE  METER READING/SCALE          41.3/2         25.8/2         35.1/2
    NOX  SAMPLE  PPM                          41.3           25.8           35.1
    NOX  BACKGRD METER READING/SCALE           1.1/2           .9/2          1.2/2
    NOX  BACKGRD PPM                           1.1             .9            1.2

    HC   CONCENTRATION PPM                     17             16             15
    CO   CONCENTRATION PPM                     64             44             61
    CO2  CONCENTRATION PCT                    1.33            .83           1.15
    NOX  CONCENTRATION PPM                    40.3           25.0           34.0
    HC   MASS GRAMS                            .54            .90            .48
    CO   MASS GRAMS                           4.16           4.95           3.92
    CO2  MASS GRAMS                        1366.96        1463.17        1176.10
    NOX  MASS GRAMS                           3.81           4.05           3.21

    WEIGHTED MASS HC         .12 GRAMS/KILOMETRE
    WEIGHTED MASS CO         .75 GRAMS/KILOMETRE
    WEIGHTED MASS CO2     225.49 GRAMS/KILOMETRE
    WEIGHTED MASS NOX        .62 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  8.44 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    207.8 STD. CU. METRES
```

## TABLE G-5. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
## VEHICLE NUMBER

```
DATE 11/21/75                  TIME     -0 HRS.          TEST NO.  1
MODEL  1975 MERCEDES 220-D SET-7 CONT,HC                 ENGINE 2.2 LITRE     4 CYL.
DRIVER   BP                    TEST WT.  1587 KG.        GVW    0 KG
WET BULB TEMP  13 C            DRY BULB TEMP  21 C       REL. HUM.  36.7 PCT
SPEC. HUM.    5.8 GRAM/KG      BARO.  748.5 MM  HG.      MEASURED FUEL  0.00 KG

  RUN DURATION            23.33 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H20
  BLOWER DIF.  PRESS. 279.4  MM  H20
  BLOWER INLET TEMP.      43  DEG. C
  DYNO REVOLUTIONS     31229
  BLOWER REVOLUTIONS     20818
  BLOWER CU. CM /REV.  8480

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE                    6.7/3
   HC  SAMPLE  PPM                                     27
   HC  BACKGRD METER READING/SCALE                    1.5/3
   HC  BACKGRD PPM                                      6
   CO  SAMPLE  METER READING/SCALE                   39.2/*
   CO  SAMPLE  PPM                                     74
   CO  BACKGRD METER READING/SCALE                    1.4/*
   CO  BACKGRD PPM                                      3
   CO2 SAMPLE  METER READING/SCALE                   55.1/2
   CO2 SAMPLE  PERCENT                               1.62
   CO2 BACKGRD METER READING/SCALE                    3.2/2
   CO2 BACKGRD PERCENT                                .08
   NOX SAMPLE  METER READING/SCALE                   52.0/2
   NOX SAMPLE  PPM                                   52.0
   NOX BACKGRD METER READING/SCALE                    1.4/2
   NOX BACKGRD PPM                                    1.4
   SO2 SAMPLE METER READING/SCALE                   44.4/*
   SO2 SAMPLE  PPM                                   11.1
   SO2 BACKGRD METER READING/SCALE                     .6/*
   SO2 BACKGRD PPM                                     .1

   HC  CONCENTRATION PPM                               21
   CO  CONCENTRATION PPM                               68
   CO2 CONCENTRATION PCT                             1.54
   NOX CONCENTRATION PPM                             50.8
   SO2 COCENTRATION PPM                             11.0
   HC  MASS (GRAMS)                                  1.94
   CO  MASS (GRAMS)                                 12.49
   CO2 MASS (GRAMS)                               4461.10
   NOX MASS (GRAMS)                                 13.12
   SO2 MASS (GRAMS)                                  4.70

HC  GRAMS/KILOMETRE       .09
CO  GRAMS/KILOMETRE       .57
CO2 GRAMS/KILOMETRE    205
NOX GRAMS/KILOMETRE       .60
SO2 GRAMS/KILOMETRE       .22

HC  GRAMS/KG OF FUEL   1.38     HC  GRAMS/MIN    .08
CO  GRAMS/KG OF FUEL    8.8     CO  GRAMS/MIN     .5
CO2 GRAMS/KG OF FUEL   3160     CO2 GRAMS/MIN    191
NOX GRAMS/KG OF FUEL   4.29     NOX GRAMS/MIN    .56
SO2 GRAMS/KG OF FUEL   3.33     SO2 GRAMS/MIN    .20
```

```
         TABLE  G-6.   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
                                VEHICLE NUMBER

DATE 11/24/75                TIME    =0 HRS.          TEST NO.  2
MODEL  1975 MERCEDES 220D    SET-7 CONT. HC           ENGINE 2.2 LITRE I  4 CYL.
DRIVER   BP                  TEST WT.  1587 KG.       GVW    0 KG
WET BULB TEMP  12 C          DRY BULB TEMP  21 C      REL. HUM.  29.6 PCT
SPEC. HUM.   4.6 GRAM/KG     BARO.  744.6 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION            23.32 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.      43  DEG. C
  DYNO REVOLUTIONS     31537
  BLOWER REVOLUTIONS     20818
  BLOWER CU. CM /REV.  8445

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE                  6.2/3
   HC   SAMPLE  PPM                                   25
   HC   BACKGRD METER READING/SCALE                  3.2/3
   HC   BACKGRD PPM                                   13
   CO   SAMPLE  METER READING/SCALE                 37.6/*
   CO   SAMPLE  PPM                                   71
   CO   BACKGRD METER READING/SCALE                   .3/*
   CO   BACKGRD PPM                                    1
   CO2 SAMPLE  METER READING/SCALE                  54.0/2
   CO2 SAMPLE  PERCENT                              1.58
   CO2 BACKGRD METER READING/SCALE                   2.2/2
   CO2 BACKGRD PERCENT                               .06
   NOX SAMPLE  METER READING/SCALE                  50.3/2
   NOX SAMPLE  PPM                                  50.3
   NOX BACKGRD METER READING/SCALE                   1.3/2
   NOX BACKGRD PPM                                   1.3
   SO2 SAMPLE METER READING/SCALE                 51.7/*
   SO2 SAMPLE  PPM                                12.9
   SO2 BACKGRD METER READING/SCALE                   .5/*
   SO2 BACKGRD PPM                                   .1

   HC  CONCENTRATION PPM                              13
   CO  CONCENTRATION PPM                              67
   CO2 CONCENTRATION PCT                            1.53
   NOX CONCENTRATION PPM                            49.2
   SO2 COCENTRATION PPM                           12.8
   HC  MASS (GRAMS)                                 1.21
   CO  MASS (GRAMS)                                12.31
   CO2 MASS (GRAMS)                              4411.36
   NOX MASS (GRAMS)                                12.27
   SO2 MASS (GRAMS)                                 5.48

HC  GRAMS/KILOMETRE       .06
CO  GRAMS/KILOMETRE       .57
CO2 GRAMS/KILOMETRE   203
NOX GRAMS/KILOMETRE       .56
SO2 GRAMS/KILOMETRE       .25

HC  GRAMS/KG OF FUEL     .87     HC  GRAMS/MIN     .05
CO  GRAMS/KG OF FUEL     8.8     CO  GRAMS/MIN      .5
CO2 GRAMS/KG OF FUEL   3162      CO2 GRAMS/MIN    189
NOX GRAMS/KG OF FUEL    8.79     NOX GRAMS/MIN     .53
SO2 GRAMS/KG OF FUEL    3.92     SO2 GRAMS/MIN     .23
```

```
          TABLE G-7.   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
                              VEHICLE NUMBER

DATE 11/25/75                 TIME     -0 HRS.         TEST NO.  3
MODEL  1975 MERCEDES 220-D SET-7 CONT,HC               ENGINE 2.2 LITRE    4 CYL.
DRIVER   BP                   TEST WT.  1587 KG.       GVW    0 KG
WET BULB TEMP  13 C           DRY BULB TEMP  21 C      REL. HUM.  43.5 PCT
SPEC. HUM.   6.7 GRAM/KG      BARO.  739.1 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION          23.33 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 309.9  MM  H2O
  BLOWER INLET TEMP.     44  DEG. C
  DYNO REVOLUTIONS     31346
  BLOWER REVOLUTIONS .  20814
  BLOWER CU. CM /REV.  8426

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE               10.4/2
   HC  SAMPLE  PPM                                 21
   HC  BACKGRD METER READING/SCALE                5.5/2
   HC  BACKGRD PPM                                 11
   CO  SAMPLE  METER READING/SCALE               35.0/*
   CO  SAMPLE  PPM                                 66
   CO  BACKGRD METER READING/SCALE                 .1/*
   CO  BACKGRD PPM                                  0
   CO2 SAMPLE  METER READING/SCALE               52.2/2
   CO2 SAMPLE  PERCENT                           1.52
   CO2 BACKGRD METER READING/SCALE                2.8/2
   CO2 BACKGRD PERCENT                            .07
   NOX SAMPLE  METER READING/SCALE               48.4/2
   NOX SAMPLE  PPM                               48.4
   NOX BACKGRD METER READING/SCALE                1.8/2
   NOX BACKGRD PPM                                1.8
   SO2 SAMPLE METER READING/SCALE               53.4/*
   SO2 SAMPLE  PPM                              13.4
   SO2 BACKGRD METER READING/SCALE                 .5/*
   SO2 BACKGRD PPM                                 .1

   HC  CONCENTRATION PPM                           11
   CO  CONCENTRATION PPM                           63
   CO2 CONCENTRATION PCT                         1.46
   NOX CONCENTRATION PPM                         46.8
   SO2 COCENTRATION PPM                         13.2
   HC  MASS (GRAMS)                               .98
   CO  MASS (GRAMS)                             11.25
   CO2 MASS (GRAMS)                           4116.05
   NOX MASS (GRAMS)                             12.14
   SO2 MASS (GRAMS)                              5.54

HC  GRAMS/KILOMETRE       .04
CO  GRAMS/KILOMETRE       .52
CO2 GRAMS/KILOMETRE    189
NOX GRAMS/KILOMETRE       .56
SO2 GRAMS/KILOMETRE       .25

HC  GRAMS/KG OF FUEL    .75     HC  GRAMS/MIN    .04
CO  GRAMS/KG OF FUEL   8.6      CO  GRAMS/MIN     .5
CO2 GRAMS/KG OF FUEL  3163      CO2 GRAMS/MIN    176
NOX GRAMS/KG OF FUEL  9.33      NOX GRAMS/MIN    .52
SO2 GRAMS/KG OF FUEL  4.26      SO2 GRAMS/MIN    .24
```

```
      TABLE  G-8.   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE  - FET
                            VEHICLE NUMBER

DATE 11/21/75                 TIME     -0 HRS.         TEST NO.  1
MODEL  1975 MERCEDES 220-D FET CONT. HC                ENGINE 2.2 LITRE    4 CYL.
DRIVER   BP                   TEST WT.  1587 KG.       GVW    0 KG
WET BULB TEMP  13 C           DRY BULB TEMP  21 C      REL. HUM.  36.7 PCT
SPEC. HUM.   5.8 GRAM/KG     BARO.  748.5 MM  HG.    MEASURED FUEL  0.00 KG

   RUN DURATION           12.78 MINUTES
   BLOWER INLET PRESS. 254.0  MM. H20
   BLOWER DIF.  PRESS. 304.8  MM  H20
   BLOWER INLET TEMP,      43  DEG. C
   DYNO REVOLUTIONS     24107
   BLOWER REVOLUTIONS     11404
   BLOWER CU. CM /REV.  8444

   BAG RESULTS
    HC   SAMPLE  METER READING/SCALE              9.4/3
    HC   SAMPLE  PPM                               38
    HC   BACKGRD METER READING/SCALE              1.9/3
    HC   BACKGRD PPM                                6
    CO   SAMPLE  METER READING/SCALE             46.3/*
    CO   SAMPLE  PPM                               87
    CO   BACKGRD METER READING/SCALE              1.6/*
    CO   BACKGRD PPM                                3
    CO2  SAMPLE  METER READING/SCALE             69.2/2
    CO2  SAMPLE  PERCENT                         2.10
    CO2  BACKGRD METER READING/SCALE              3.1/2
    CO2  BACKGRD PERCENT                          .08
    NOX  SAMPLE  METER READING/SCALE             71.6/2
    NOX  SAMPLE  PPM                             71.6
    NOX  BACKGRD METER READING/SCALE              1.4/2
    NOX  BACKGRD PPM                              1.4
    SO2  SAMPLE METER READING/SCALE             67.2/*
    SO2  SAMPLE  PPM                             16.8
    SO2  BACKGRD METER READING/SCALE              1.1/*
    SO2  BACKGRD PPM                               .3

    HC   CONCENTRATION PPM                         31
    CO   CONCENTRATION PPM                         80
    CO2  CONCENTRATION PCT                       2.03
    NOX  CONCENTRATION PPM                       70.4
    SO2  COCENTRATION PPM                       16.6
    HC   MASS (GRAMS)                            1.54
    CO   MASS (GRAMS)                            7.96
    CO2  MASS (GRAMS)                         3198.31
    NOX  MASS (GRAMS)                            9.92
    SO2  MASS (GRAMS)                            3.87

HC   GRAMS/KILOMETRE        .09
CO   GRAMS/KILOMETRE        .48
CO2  GRAMS/KILOMETRE    194
NOX  GRAMS/KILOMETRE        .60
SO2  GRAMS/KILOMETRE        .23

HC   GRAMS/KG OF FUEL    1.52      HC   GRAMS/MIN     .12
CO   GRAMS/KG OF FUEL     7.9      CO   GRAMS/MIN      .6
CO2  GRAMS/KG OF FUEL    3161      CO2  GRAMS/MIN     250
NOX  GRAMS/KG OF FUEL    9.81      NOX  GRAMS/MIN     .78
SO2  GRAMS/KG OF FUEL    3.83      SO2  GRAMS/MIN     .30
```

```
        TABLE G-9.   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET
                             VEHICLE NUMBER

DATE 11/24/75                TIME    -0 HRS.          TEST NO.  2
MODEL  1975 MERCEDES 220D    FET CONT. HC             ENGINE 2.2 LITRE I  4 CYL.
DRIVER   BP                  TEST WT.  1587 KG.       GVW    0 KG
WET BULB TEMP  12 C          DRY BULB TEMP  21 C      REL. HUM.  29.6 PCT
SPEC. HUM.   4.6 GRAM/KG     BARO.  744.6 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION          12.78 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 317.5  MM  H2O
  BLOWER INLET TEMP.     45  DEG. C
  DYNO REVOLUTIONS    23830
  BLOWER REVOLUTIONS    11399
  BLOWER CU. CM /REV.  8418

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE                   7.0/3
   HC   SAMPLE  PPM                                    28
   HC   BACKGRD METER READING/SCALE                   2.0/3
   HC   BACKGRD PPM                                     8
   CO   SAMPLE  METER READING/SCALE                  47.0/*
   CO   SAMPLE  PPM                                    88
   CO   BACKGRD METER READING/SCALE                    .1/*
   CO   BACKGRD PPM                                     0
   CO2 SAMPLE  METER READING/SCALE                   66.7/2
   CO2 SAMPLE  PERCENT                               2.01
   CO2 BACKGRD METER READING/SCALE                   1.9/2
   CO2 BACKGRD PERCENT                               .05
   NOX SAMPLE  METER READING/SCALE                   65.3/2
   NOX SAMPLE  PPM                                   65.3
   NOX BACKGRD METER READING/SCALE                    .9/2
   NOX BACKGRD PPM                                    .9
   SO2 SAMPLE METER READING/SCALE                   75.7/*
   SO2 SAMPLE  PPM                                  18.9
   SO2 BACKGRD METER READING/SCALE                    .7/*
   SO2 BACKGRD PPM                                    .2

   HC   CONCENTRATION PPM                              21
   CO   CONCENTRATION PPM                              84
   CO2 CONCENTRATION PCT                             1.47
   NOX CONCENTRATION PPM                             64.5
   SO2 COCENTRATION PPM                             18.8
   HC   MASS (GRAMS)                                 1.03
   CO   MASS (GRAMS)                                 8.29
   CO2 MASS (GRAMS)                              3079.40
   NOX MASS (GRAMS)                                 8.75
   SO2 MASS (GRAMS)                                 4.36

HC   GRAMS/KILOMETRE       .06
CO   GRAMS/KILOMETRE       .50
CO2 GRAMS/KILOMETRE   187
NOX GRAMS/KILOMETRE       .53
SO2 GRAMS/KILOMETRE       .26

HC   GRAMS/KG OF FUEL   1.06     HC   GRAMS/MIN     .08
CO   GRAMS/KG OF FUEL    8.5     CO   GRAMS/MIN      .6
CO2 GRAMS/KG OF FUEL   3162     CO2 GRAMS/MIN     241
NOX GRAMS/KG OF FUEL   8.98     NOX GRAMS/MIN     .68
SO2 GRAMS/KG OF FUEL   4.47     SO2 GRAMS/MIN     .34
```

```
        TABLE G-10.  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE   - FET
                             VEHICLE NUMBER

DATE 11/25/75                 TIME    -0 HRS.          TEST NO.  3
MODEL  1975 MERCEDES 220-D FET CONT.HC                 ENGINE 2.2 LITRE     4 CYL.
DRIVER   BP                   TEST WT.  1587 KG.       GVW    0 KG
WET BULB TEMP  13 C           DRY BULB TEMP  21 C      REL. HUM.  43.5 PCT
SPEC. HUM.   6.7 GRAM/KG      BARO.  739.1 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION          12.76 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H20
  BLOWER DIF.  PRESS. 304.8  MM  H20
  BLOWER INLET TEMP.     45  DEG. C
  DYNO REVOLUTIONS    24015
  BLOWER REVOLUTIONS    11387
  BLOWER CU. CM /REV.  8430

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE             17.9/2
   HC  SAMPLE  PPM                               36
   HC  BACKGRD METER READING/SCALE              5.5/2
   HC  BACKGRD PPM                               11
   CO  SAMPLE  METER READING/SCALE             44.5/*
   CO  SAMPLE  PPM                               84
   CO  BACKGRD METER READING/SCALE               .2/*
   CO  BACKGRD PPM                                0
   CO2 SAMPLE  METER READING/SCALE             65.8/2
   CO2 SAMPLE  PERCENT                         1.98
   CO2 BACKGRD METER READING/SCALE              2.5/2
   CO2 BACKGRD PERCENT                          .07
   NOX SAMPLE  METER READING/SCALE             66.3/2
   NOX SAMPLE  PPM                             66.3
   NOX BACKGRD METER READING/SCALE               .6/2
   NOX BACKGRD PPM                               .6
   SO2 SAMPLE METER READING/SCALE             81.0/*
   SO2 SAMPLE  PPM                            20.2
   SO2 BACKGRD METER READING/SCALE              1.1/*
   SO2 BACKGRD PPM                               .3

   HC  CONCENTRATION PPM                         26
   CO  CONCENTRATION PPM                         79
   CO2 CONCENTRATION PCT                       1.92
   NOX CONCENTRATION PPM                       65.8
   SO2 COCENTRATION PPM                       20.0
   HC  MASS (GRAMS)                            1.28
   CO  MASS (GRAMS)                            7.70
   CO2 MASS (GRAMS)                         2967.25
   NOX MASS (GRAMS)                            9.32
   SO2 MASS (GRAMS)                            4.57

HC  GRAMS/KILOMETRE       .08
CO  GRAMS/KILOMETRE       .47
CO2 GRAMS/KILOMETRE   180
NOX GRAMS/KILOMETRE       .57
SO2 GRAMS/KILOMETRE       .24

HC  GRAMS/KG OF FUEL   1.36      HC  GRAMS/MIN     .10
CO  GRAMS/KG OF FUEL    8.2      CO  GRAMS/MIN      .6
CO2 GRAMS/KG OF FUEL   3161      CO2 GRAMS/MIN     232
NOX GRAMS/KG OF FUEL   9.93      NOX GRAMS/MIN     .73
SO2 GRAMS/KG OF FUEL   4.87      SO2 GRAMS/MIN     .36
```

## TABLE G-11. HC, CO, $NO_x$ AND FUEL RESULTS MERCEDES 240D

| Test | Date | Emission Rate g/km | | | Fuel Cons. 1/100 km | Fuel Econ. mpg |
|---|---|---|---|---|---|---|
| | | HC | CO | $NO_x$ | | |
| 1975 FTP | 11-12-75 | 0.20 | 0.62 | 0.78 | 9.51 | 24.73 |
| | 11-13-75 | 0.12 | 0.59 | 0.82 | 8.89 | 26.46 |
| | 11-14-75 | 0.21 | 0.60 | 0.76 | 9.05 | 25.99 |
| | Average | 0.18 | 0.60 | 0.79 | 9.15 | 25.72 |
| FTP Cold | 11-12-75 | 0.18 | 0.64 | 0.79 | 9.86 | 23.85 |
| | 11-13-75 | 0.12 | 0.59 | 0.84 | 9.17 | 25.79 |
| | 11-14-75 | 0.22 | 0.63 | 0.77 | 9.48 | 24.81 |
| | Average | 0.17 | 0.62 | 0.80 | 9.50 | 24.81 |
| FTP Hot | 11-12-75 | 0.12 | 0.60 | 0.78 | 9.04 | 26.02 |
| | 11-13-75 | 0.12 | 0.60 | 0.78 | 8.37 | 28.10 |
| | 11-14-75 | 0.12 | 0.58 | 0.74 | 8.43 | 28.06 |
| | Average | 0.12 | 0.59 | 0.77 | 8.61 | 27.39 |
| FET | 11-12-75 | 0.07 | 0.36 | 0.87 | 7.32 | 32.13 |
| | 11-13-75 | 0.05 | 0.39 | 0.78 | 6.72 | 35.00 |
| | 11-14-75 | 0.06 | 0.40 | 0.74 | 6.90 | 34.09 |
| | Average | 0.06 | 0.38 | 0.80 | 6.98 | 33.74 |
| SET | 11-12-75 | 0.06 | 0.46 | 0.81 | 7.46 | 31.53 |
| | 11-13-75 | 0.04 | 0.45 | 0.79 | 7.15 | 32.90 |
| | 11-14-75 | 0.09 | 0.45 | 0.74 | 7.34 | 32.04 |
| | Average | 0.06 | 0.45 | 0.78 | 7.32 | 32.16 |

```
                 TABLE G-12.            VEHICLE EMISSION RESULTS  1975 FTP
                         1975  LIGHT DUTY EMISSIONS TEST

                                        DATE 11/12/75                MFGR. CODE   OM616          .YR. 1975
UNIT NO.             TEST NO. 1         ENGINE   2.39 LITRE 4 CYL.    TEST WT.   1587 KG         ROAD LOAD    8.4 KW
VEHICLE MODEL  MERCEDES 240D LA         COMMENTS  3 BAG
TEST TYPE  -4 COLD CONT. HC
                                                                   WET BULB TEMP  11.1 DEG. C
BAROMETER 748.28 MM OF HG.                                          ABS. HUMIDITY   2.2 MILLIGRAMS/KG
DRY BULB TEMP.   25.6 DEG. C
REL. HUMIDITY      11 PCT.
EXHAUST EMISSIONS
                                                                   BLOWER INLET PRESS., G1 139.7 MM. H2O
    BLOWER DIF. PRESS., G2, 165.1 MM. H2O                          BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
                                              1                2                3
    BAG NO.                                5458             9357             5979
    BLOWER REVOLUTIONS                    11.3/3            8.2/3           14.8/3
    HC    SAMPLE  METER READING/SCALE         45               33               59
    HC    SAMPLE  PPM                        1.5/3            1.5/3            4.5/2
    HC    BACKGRD METER READING/SCALE          6                6                9
    HC    BACKGRD PPM                       41.0/*           26.5/*           32.1/*
    CO    SAMPLE  METER READING/SCALE         77               50               61
    CO    SAMPLE  PPM                         .4/*             .5/*             .8/*
    CO    BACKGRD METER READING/SCALE          1                1                2
    CO    BACKGRD PPM                       67.5/2           43.3/2           56.0/2
    CO2   SAMPLE  METER READING/SCALE       2.04             1.24             1.65
    CO2   SAMPLE  PERCENT                    2.0/2            1.7/2            2.7/2
    CO2   BACKGRD METER READING/SCALE        .05              .04              .07
    CO2   BACKGRD PERCENT                   73.4/2           45.9/2           63.4/2
    NOX   SAMPLE  METER READING/SCALE       73.4             45.9             63.4
    NOX   SAMPLE  PPM                        1.1/2             .9/2            1.3/2
    NOX   BACKGRD METER READING/SCALE        1.1               .9              1.3
    NOX   BACKGRD PPM
                                              40               27               51
    HC    CONCENTRATION PPM                   73               48               57
    CO    CONCENTRATION PPM                 2.00             1.20             1.59
    CO2   CONCENTRATION PCT                 72.5             45.1             62.3
    NOX   CONCENTRATION PPM                  .99             1.15             1.38
    HC    MASS GRAMS                        3.64             4.08             3.11
    CO    MASS GRAMS                     1566.91          1614.57          1365.00
    CO2   MASS GRAMS                        4.63       [illegible].94         4.36
    NOX   MASS GRAMS

    WEIGHTED MASS HC        .20 GRAMS/KILOMETRE
    WEIGHTED MASS CO        .62 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    254.10 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .78 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  9.51 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   162.7 STD. CU. METRES
```

```
                    TABLE G-13.                      VEHICLE EMISSION RESULTS - 1975 FTP
                             1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.               TEST NO. 2            DATE 11/13/75
VEHICLE MODEL  MERCEDES 240D LA              ENGINE   2.39 LITRE 4 CYL.      MFGR. CODE   OM616          YR. 1975
TEST TYPE  -4 COLD CONT. HC                  COMMENTS  3 BAG                  TEST WT.  1587  KG             ROAD LOAD   8.4 KW

BAROMETER 750.82 MM OF HG.
DRY BULB TEMP.   25.6 DEG. C                                       WET BULB TEMP  13.3 DEG. C
REL. HUMIDITY     22 PCT.                                           ABS. HUMIDITY   4.4 MILLIGRAMS/KG
EXHAUST EMISSIONS

    BLOWER DIF. PRESS., G2, 242.1 MM. H2O                          BLOWER INLET PRESS., G1 241.3 MM. H2O
                                                                   BLOWER INLET TEMP.   43 DEG. C
    BAG RESULTS
    BAG NO.
    BLOWER REVOLUTIONS                               1              2              3
    HC    SAMPLE  METER READING/SCALE              7523          12961           7525
    HC    SAMPLE  PPM                              18.6/2          9.8/2         17.7/2
    HC    BACKGRD METER READING/SCALE               37             20             35
    HC    BACKGRD PPM                               5.0/2          5.0/2          6.0/2
    CO    SAMPLE  METER READING/SCALE               10             10             12
    CO    SAMPLE  PPM                              45.1/*         30.0/*         28.8/*
    CO    BACKGRD METER READING/SCALE               85             57             54
    CO    BACKGRD PPM                              21.3/*         11.2/*          3.6/*
    CO2   SAMPLE  METER READING/SCALE               40             21              7
    CO2   SAMPLE  PERCENT                          50.2/2         32.3/2         45.4/2
    CO2   BACKGRD METER READING/SCALE              1.46            .90           1.31
    CO2   BACKGRD PERCENT                           2.4/2          3.1/2          2.4/2
    NOX   SAMPLE  METER READING/SCALE               .06            .08            .06
    NOX   SAMPLE  PPM                              56.7/2         34.5/2         52.9/2
    NOX   BACKGRD METER READING/SCALE              56.7           34.5           52.9
    NOX   BACKGRD PPM                               1.7/2          1.5/2          1.6/2
                                                    1.7            1.5            1.6
    HC    CONCENTRATION PPM
    CO    CONCENTRATION PPM                         28             10             25
    CO2   CONCENTRATION PCT                         46             36             47
    NOX   CONCENTRATION PPM                        1.40            .83           1.25
    HC    MASS GRAMS                               55.2           33.1           51.5
    CO    MASS GRAMS                                .93            .58            .81
    CO2   MASS GRAMS                               3.05           4.06           3.08
    NOX   MASS GRAMS                            1467.60        1491.15        1306.74
                                                   4.98           5.15           4.64
    WEIGHTED MASS HC         .12 GRAMS/KILOMETRE
    WEIGHTED MASS CO         .54 GRAMS/KILOMETRE
    WEIGHTED MASS CO2     237.54 GRAMS/KILOMETRE
    WEIGHTED MASS NOX        .82 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  8.84 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   211.9 STD. CU. METRES
```

```
                          TABLE G-14             VEHICLE EMISSION RESULTS -  1975 FTP
                                 1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 3         DATE 11/14/75                  MFGR. CODE   OM616                YR. 1975
VEHICLE MODEL  MERCEDES 240D LA          ENGINE   2.39 LITRE 4 CYL.     TEST WT.  1587 KG                 ROAD LOAD   8.4 KW
TEST TYPE  -4 COLD CONT.HC               COMMENTS  3 BAG

BAROMETER 750.32 MM OF HG.                                            WET BULB TEMP  10.6 DEG. C
DRY BULB TEMP.   21.1 DEG. C                                           ABS. HUMIDITY   3.5 MILLIGRAMS/KG
REL. HUMIDITY      23 PCT.
EXHAUST EMISSIONS

                                                                      BLOWER INLET PRESS., G1 279.4 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                             BLOWER INLET TEMP.   43 DEG. C

    BAG RESULTS
    BAG NO.                                          1               2                3
    BLOWER REVOLUTIONS                            7521           12907             7514
    HC    SAMPLE  METER READING/SCALE           23.0/2          16.3/2           18.3/2
    HC    SAMPLE  PPM                               46              33               37
    HC    BACKGRD METER READING/SCALE            4.5/2           4.0/2            4.5/2
    HC    BACKGRD PPM                                9               8                9
    CO    SAMPLE  METER READING/SCALE           32.1/*          22.1/*           26.2/*
    CO    SAMPLE  PPM                               61              42               50
    CO    BACKGRD METER READING/SCALE            2.8/*           2.5/*            2.0/*
    CO    BACKGRD PPM                                5               5                4
    CO2   SAMPLE  METER READING/SCALE           52.6/2          33.7/2           45.0/2
    CO2   SAMPLE  PERCENT                       1.54             .95             1.29
    CO2   BACKGRD METER READING/SCALE            3.0/2           3.5/2            2.6/2
    CO2   BACKGRD PERCENT                         .08             .09              .07
    NOX   SAMPLE  METER READING/SCALE           53.2/2          33.5/2           50.1/2
    NOX   SAMPLE  PPM                           53.2            33.5             50.1
    NOX   BACKGRD METER READING/SCALE            1.9/2           1.9/2            1.7/2
    NOX   BACKGRD PPM                            1.9             1.9              1.7

    HC    CONCENTRATION PPM                        38              25               29
    CO    CONCENTRATION PPM                        54              36               45
    CO2   CONCENTRATION PCT                      1.47             .86             1.23
    NOX   CONCENTRATION PPM                      51.5            31.7             48.6
    HC    MASS GRAMS                             1.24            1.41              .93
    CO    MASS GRAMS                             3.53            4.11             2.93
    CO2   MASS GRAMS                          1523.98         1532.10          1277.86
    NOX   MASS GRAMS                             4.50            4.76             4.24

    WEIGHTED MASS HC        .21 GRAMS/KILOMETRE
    WEIGHTED MASS CO        .60 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    241.62 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .76 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  9.05 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   204.9 STD. CU. METRES
```

```
              TABLE G-15.   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
                                   VEHICLE NUMBER

DATE 11/12/75                 TIME     -0 HRS.           TEST NO.  1
MODEL  1975 MERCEDES 240D  SET 7 CONT. HC             ENGINE 2.4 LITRE     4 CYL.
DRIVER   GP                   TEST WT.  1587 KG.      GVW     0 KG
WET BULB TEMP  13 C           DRY BULB TEMP  26 C     REL. HUM.  21.8 PCT
SPEC. HUM.   4.5 GRAM/KG      BARO.  748.3 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION           23.35 MINUTES
  BLOWER INLET PRESS. 139.7  MM. H2O
  BLOWER DIF.  PRESS. 165.1  MM  H2O
  BLOWER INLET TEMP.      44  DEG. C
  DYNO REVOLUTIONS     31453
  BLOWER REVOLUTIONS    15115
  BLOWER CU. CM /REV.  8698

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE               16.6/2
   HC  SAMPLE  PPM                                  33
   HC  BACKGRD METER READING/SCALE                7.5/2
   HC  BACKGRD PPM                                  15
   CO  SAMPLE  METER READING/SCALE               41.4/*
   CO  SAMPLE  PPM                                  78
   CO  BACKGRD METER READING/SCALE                 .5/*
   CO  BACKGRD PPM                                   1
   CO2 SAMPLE  METER READING/SCALE               67.5/2
   CO2 SAMPLE  PERCENT                           2.04
   CO2 BACKGRD METER READING/SCALE                2.2/2
   CO2 BACKGRD PERCENT                            .06
   NOX SAMPLE  METER READING/SCALE               32.0/3
   NOX SAMPLE  PPM                               96.0
   NOX BACKGRD METER READING/SCALE                 .7/3
   NOX BACKGRD PPM                                2.1
   SO2 SAMPLE METER READING/SCALE               65.3/*
   SO2 SAMPLE  PPM                               16.3
   SO2 BACKGRD METER READING/SCALE                 .4/*
   SO2 BACKGRD PPM                                 .1

   HC  CONCENTRATION PPM                           20
   CO  CONCENTRATION PPM                           73
   CO2 CONCENTRATION PCT                         1.99
   NOX CONCENTRATION PPM                         94.2
   SO2 COCENTRATION PPM                         16.3
   HC  MASS (GRAMS)                              1.39
   CO  MASS (GRAMS)                             10.08
   CO2 MASS (GRAMS)                           4313.54
   NOX MASS (GRAMS)                             17.62
   SO2 MASS (GRAMS)                              5.22

HC  GRAMS/KILOMETRE        .06
CO  GRAMS/KILOMETRE        .46
CO2 GRAMS/KILOMETRE    198
NOX GRAMS/KILOMETRE        .81
SO2 GRAMS/KILOMETRE        .24

HC  GRAMS/KG OF FUEL   1.02      HC  GRAMS/MIN     .06
CO  GRAMS/KG OF FUEL    7.4      CO  GRAMS/MIN      .4
CO2 GRAMS/KG OF FUEL   3164      CO2 GRAMS/MIN     185
NOX GRAMS/KG OF FUEL  12.92      NOX GRAMS/MIN     .75
SO2 GRAMS/KG OF FUEL   3.83      SO2 GRAMS/MIN     .22
```

### TABLE G-16. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
### VEHICLE NUMBER

```
                                 TIME  1520 HRS.          TEST NO.  2
DATE 11/13/75                                             ENGINE 2.4 LITRE I  4 CYL.
MODEL  1975 MERCEDES 240D SET-7 CONT. HC                  GVW    0 KG
DRIVER   BP                      TEST WT.  1587 KG.       REL. HUM.  34.9 PCT
WET BULB TEMP  15 C              DRY BULB TEMP  24 C      MEASURED FUEL  0.00 KG
SPEC. HUM.   6.7 GRAM/KG         BARO.  750.8 MM  HG.

  RUN DURATION             23.34 MINUTES
  BLOWER INLET PRESS. 241.3  MM. H2O
  BLOWER DIF.  PRESS. 292.1  MM  H2O
  BLOWER INLET TEMP.      43  DEG. C
  DYNO REVOLUTIONS     31530
  BLOWER REVOLUTIONS     20821
  BLOWER CU. CM /REV.  8464

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE                 7.1/2
   HC  SAMPLE  PPM                                  14
   HC  BACKGRD METER READING/SCALE                 3.0/2
   HC  BACKGRD PPM                                   6
   CO  SAMPLE  METER READING/SCALE                30.5/*
   CO  SAMPLE  PPM                                  58
   CO  BACKGRD METER READING/SCALE                  .9/*
   CO  BACKGRD PPM                                   2
   CO2 SAMPLE  METER READING/SCALE                51.5/2
   CO2 SAMPLE  PERCENT                            1.50
   CO2 BACKGRD METER READING/SCALE                 3.1/2
   CO2 BACKGRD PERCENT                             .08
   NOX SAMPLE  METER READING/SCALE                65.7/2
   NOX SAMPLE  PPM                                65.7
   NOX BACKGRD METER READING/SCALE                 1.6/2
   NOX BACKGRD PPM                                 1.6
   SO2 SAMPLE METER READING/SCALE                51.3/*
   SO2 SAMPLE  PPM                                12.8
   SO2 BACKGRD METER READING/SCALE                  .4/*
   SO2 BACKGRD PPM                                  .1

   HC  CONCENTRATION PPM                             9
   CO  CONCENTRATION PPM                            54
   CO2 CONCENTRATION PCT                          1.43
   NOX CONCENTRATION PPM                          64.3
   SO2 CUCENTRATION PPM                           12.7
   HC  MASS (GRAMS)                                .81
   CO  MASS (GRAMS)                               9.86
   CO2 MASS (GRAMS)                            4136.44
   NOX MASS (GRAMS)                              17.10
   SO2 MASS (GRAMS)                               5.47

 HC  GRAMS/KILOMETRE        .04
 CO  GRAMS/KILOMETRE        .45
 CO2 GRAMS/KILOMETRE     190
 NOX GRAMS/KILOMETRE        .74
 SO2 GRAMS/KILOMETRE        .25

 HC  GRAMS/KG OF FUEL     .62       HC  GRAMS/MIN     .03
 CO  GRAMS/KG OF FUEL    7.5        CO  GRAMS/MIN     .4
 CO2 GRAMS/KG OF FUEL   3165        CO2 GRAMS/MIN    177
 NOX GRAMS/KG OF FUEL  13.09        NOX GRAMS/MIN     .73
 SO2 GRAMS/KG OF FUEL   4.18        SO2 GRAMS/MIN     .23
```

## TABLE G-17. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
## VEHICLE NUMBER

```
DATE 11/14/75                TIME    -0 HRS.          TEST NO.  3
MODEL  1975 MERCEDES 240D SET-7 CONT. HC              ENGINE 2.4 LITRE I  4 CYL.
DRIVER   BP                  TEST WT.  1587 KG.       GVW    0 KG
WET BULB TEMP  12 C          DRY BULB TEMP  24 C      REL. HUM.  21.6 PCT
SPEC. HUM.   4.0 GRAM/KG     BARO.  750.3 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION           23.34 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 317.5  MM  H2O
  BLOWER INLET TEMP.     46  DEG. C
  DYNO REVOLUTIONS     31766
  BLOWER REVOLUTIONS     20822
  BLOWER CU. CM /REV.  8412

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE              15.3/2
   HC  SAMPLE  PPM                                31
   HC  BACKGRD METER READING/SCALE               4.5/2
   HC  BACKGRD PPM                                 9
   CO  SAMPLE  METER READING/SCALE              30.7/*
   CO  SAMPLE  PPM                                58
   CO  BACKGRD METER READING/SCALE               1.0/*
   CO  BACKGRD PPM                                 2
   CO2 SAMPLE  METER READING/SCALE              53.0/2
   CO2 SAMPLE  PERCENT                          1.55
   CO2 BACKGRD METER READING/SCALE               2.6/2
   CO2 BACKGRD PERCENT                           .07
   NOX SAMPLE  METER READING/SCALE              67.0/2
   NOX SAMPLE  PPM                              67.0
   NOX BACKGRD METER READING/SCALE               1.2/2
   NOX BACKGRD PPM                               1.2
   SO2 SAMPLE METER READING/SCALE              50.9/*
   SO2 SAMPLE  PPM                              12.7
   SO2 BACKGRD METER READING/SCALE                .4/*
   SO2 BACKGRD PPM                                .1

   HC  CONCENTRATION PPM                          23
   CO  CONCENTRATION PPM                          54
   CO2 CONCENTRATION PCT                        1.49
   NOX CONCENTRATION PPM                        65.9
   SO2 COCENTRATION PPM                        12.6
   HC  MASS (GRAMS)                             2.02
   CO  MASS (GRAMS)                             9.77
   CO2 MASS (GRAMS)                          4241.13
   NOX MASS (GRAMS)                            16.00
   SO2 MASS (GRAMS)                             5.34

 HC  GRAMS/KILOMETRE       .09
 CO  GRAMS/KILOMETRE       .45
 CO2 GRAMS/KILOMETRE   195
 NOX GRAMS/KILOMETRE       .74
 SO2 GRAMS/KILOMETRE       .25

 HC  GRAMS/KG OF FUEL   1.51     HC  GRAMS/MIN    .09
 CO  GRAMS/KG OF FUEL    7.3     CO  GRAMS/MIN     .4
 CO2 GRAMS/KG OF FUEL   3162     CO2 GRAMS/MIN    182
 NOX GRAMS/KG OF FUEL  11.93     NOX GRAMS/MIN    .69
 SO2 GRAMS/KG OF FUEL   3.98     SO2 GRAMS/MIN    .23
```

## TABLE G-18. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - HWFET
## VEHICLE NUMBER

```
DATE 11/12/75                TIME  1133 HRS.          TEST NO.  1
MODEL  1975 MERCEDES 240D    HWFET  CONT. HC          ENGINE84.3 LITRE     4 CYL.
DRIVER   BP                  TEST WT.  1587 KG.       GVW    0 KG
WET BULB TEMP  13 C          DRY BULB TEMP  26 C      REL. HUM.  19.0 PCT
SPEC. HUM.   3.9 GRAM/KG     BARO.  748.3 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION           12.77 MINUTES
  BLOWER INLET PRESS. 139.7  MM. H2O
  BLOWER DIF.  PRESS. 165.1  MM  H2O
  BLOWER INLET TEMP.      43  DEG. C
  DYNO REVOLUTIONS     23958
  BLOWER REVOLUTIONS      8271
  BLOWER CU. CM /REV.  8700

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE            17.9/2
   HC   SAMPLE  PPM                             36
   HC   BACKGRD METER READING/SCALE             4.0/2
   HC   BACKGRD PPM                              8
   CO   SAMPLE  METER READING/SCALE            55.4/*
   CO   SAMPLE  PPM                            104
   CO   BACKGRD METER READING/SCALE            11.9/*
   CO   BACKGRD PPM                             23
   CO2  SAMPLE  METER READING/SCALE            86.8/2
   CO2  SAMPLE  PERCENT                        2.74
   CO2  BACKGRD METER READING/SCALE             2.2/2
   CO2  BACKGRD PERCENT                         .06
   NOX  SAMPLE  METER READING/SCALE            47.6/3
   NOX  SAMPLE  PPM                           142.8
   NOX  BACKGRD METER READING/SCALE             1.1/2
   NOX  BACKGRD PPM                             1.1
   SO2  SAMPLE METER READING/SCALE             97.1/*
   SO2  SAMPLE  PPM                            24.3
   SO2  BACKGRD METER READING/SCALE              .7/*
   SO2  BACKGRD PPM                              .2

   HC   CONCENTRATION PPM                       29
   CO   CONCENTRATION PPM                       80
   CO2  CONCENTRATION PCT                     2.70
   NOX  CONCENTRATION PPM                    141.9
   SO2  COCENTRATION PPM                      24.1
   HC   MASS (GRAMS)                          1.10
   CO   MASS (GRAMS)                          6.00
   CO2  MASS (GRAMS)                       3211.30
   NOX  MASS (GRAMS)                         14.35
   SO2  MASS (GRAMS)                          4.26

HC   GRAMS/KILOMETRE       .07
CO   GRAMS/KILOMETRE       .36
CO2  GRAMS/KILOMETRE    195
NOX  GRAMS/KILOMETRE       .87
SO2  GRAMS/KILOMETRE       .26

HC   GRAMS/KG OF FUEL   1.08     HC   GRAMS/MIN     .09
CO   GRAMS/KG OF FUEL    5.9     CO   GRAMS/MIN      .5
CO2  GRAMS/KG OF FUEL   3166     CO2  GRAMS/MIN     251
NOX  GRAMS/KG OF FUEL  14.15     NOX  GRAMS/MIN    1.12
SO2  GRAMS/KG OF FUEL   4.20     SO2  GRAMS/MIN     .33
```

## TABLE G-19. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET
## VEHICLE NUMBER

```
DATE 11/13/75                 TIME     -0 HRS.           TEST NO.  2
MODEL  1975 MERCEDES 240D FET CONT. HC                   ENGINE 2.4 LITRE I  4 CYL.
DRIVER   BP                   TEST WT.  1587 KG.         GVW    0 KG
WET BULB TEMP  15 C           DRY BULB TEMP  24 C        REL. HUM.  34.9 PCT
SPEC. HUM.   6.7 GRAM/KG      BARO.  750.8 MM  HG.       MEASURED FUEL  0.00 KG

  RL  DURATION           12.77 MINUTES
  BLOWER INLET PRESS. 241.3  MM. H2O
  BLOWER DIF.  PRESS. 292.1  MM  H2O
  BLOWER INLET TEMP.     43  DEG. C
  DYNO REVOLUTIONS    23838
  BLOWER REVOLUTIONS    11393
  BLOWER CU. CM /REV.  8464

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE              10.4/2
   HC  SAMPLE  PPM                                21
   HC  BACKGRD METER READING/SCALE               2.0/2
   HC  BACKGRD PPM                                 4
   CO  SAMPLE  METER READING/SCALE              36.8/*
   CO  SAMPLE  PPM                                69
   CO  BACKGRD METER READING/SCALE               1.3/*
   CO  BACKGRD PPM                                 2
   CO2 SAMPLE  METER READING/SCALE              64.0/2
   CO2 SAMPLE  PERCENT                          1.92
   CO2 BACKGRD METER READING/SCALE               2.6/2
   CO2 BACKGRD PERCENT                           .07
   NOX SAMPLE  METER READING/SCALE              90.0/2
   NOX SAMPLE  PPM                              90.0
   NOX BACKGRD METER READING/SCALE               1.9/2
   NOX BACKGRD PPM                               1.9
   SO2 SAMPLE METER READING/SCALE              74.7/*
   SO2 SAMPLE  PPM                              18.7
   SO2 BACKGRD METER READING/SCALE                .8/*
   SO2 BACKGRD PPM                                .2

   HC  CONCENTRATION PPM                          17
   CO  CONCENTRATION PPM                          64
   CO2 CONCENTRATION PCT                        1.86
   NOX CONCENTRATION PPM                        88.4
   SO2 COCENTRATION PPM                        18.5
   HC  MASS (GRAMS)                              .86
   CO  MASS (GRAMS)                             6.41
   CO2 MASS (GRAMS)                          2946.58
   NOX MASS (GRAMS)                            12.87
   SO2 MASS (GRAMS)                             4.35

HC  GRAMS/KILOMETRE       .05
CO  GRAMS/KILOMETRE       .34
CO2 GRAMS/KILOMETRE   179
NOX GRAMS/KILOMETRE       .78
SO2 GRAMS/KILOMETRE       .26

HC  GRAMS/KG OF FUEL    .93     HC  GRAMS/MIN     .07
CO  GRAMS/KG OF FUEL    6.9     CO  GRAMS/MIN      .5
CO2 GRAMS/KG OF FUEL   3165     CO2 GRAMS/MIN     231
NOX GRAMS/KG OF FUEL  13.82     NOX GRAMS/MIN    1.01
SO2 GRAMS/KG OF FUEL   4.67     SO2 GRAMS/MIN     .34
```

## TABLE G-20. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET
## VEHICLE NUMBER

```
DATE 11/14/75                  TIME     -0 HRS.          TEST NO.  3
MODEL  1975 MERCEDES 240D FET CONT. HC                   ENGINE 2.4 LITRE     4 CYL.
DRIVER   BP                    TEST WT.  1587 KG.        GVW    0 KG
WET BULB TEMP  12 C            DRY BULB TEMP  24 C       REL. HUM.  21.6 PCT
SPEC. HUM.   4.0 GRAM/KG       BARO.  750.3 MM  HG.      MEASURED FUEL  0.00 KG

  RUN DURATION          12.76 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H20
  BLOWER DIF.  PRESS. 317.5  MM  H20
  BLOWER INLET TEMP.     43  DEG. C
  DYNO REVOLUTIONS    23401
  BLOWER REVOLUTIONS    11389
  BLOWER CU. CM /REV.  8428

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE               15.9/2
   HC  SAMPLE  PPM                                 32
   HC  BACKGRD METER READING/SCALE                7.0/2
   HC  BACKGRD PPM                                 14
   CO  SAMPLE  METER READING/SCALE               39.6/*
   CO  SAMPLE  PPM                                 75
   CO  BACKGRD METER READING/SCALE                3.6/*
   CO  BACKGRD PPM                                  7
   CO2 SAMPLE  METER READING/SCALE               66.0/2
   CO2 SAMPLE  PERCENT                           1.99
   CO2 BACKGRD METER READING/SCALE                2.9/2
   CO2 BACKGRD PERCENT                            .08
   NOX SAMPLE  METER READING/SCALE               92.8/2
   NOX SAMPLE  PPM                               92.8
   NOX BACKGRD METER READING/SCALE                1.8/2
   NOX BACKGRD PPM                                1.8
   SO2 SAMPLE METER READING/SCALE               85.0/*
   SO2 SAMPLE  PPM                              21.3
   SO2 BACKGRD METER READING/SCALE                 .9/*
   SO2 BACKGRD PPM                                 .2

   HC  CONCENTRATION PPM                           20
   CO  CONCENTRATION PPM                           65
   CO2 CONCENTRATION PCT                         1.92
   NOX CONCENTRATION PPM                         91.3
   SO2 COCENTRATION PPM                         21.1
   HC  MASS (GRAMS)                               .98
   CO  MASS (GRAMS)                              6.51
   CO2 MASS (GRAMS)                           3025.97
   NOX MASS (GRAMS)                             12.24
   SO2 MASS (GRAMS)                              4.92

HC  GRAMS/KILOMETRE       .06
CO  GRAMS/KILOMETRE       .40
CO2 GRAMS/KILOMETRE   184
NOX GRAMS/KILOMETRE       .74
SO2 GRAMS/KILOMETRE       .30

HC  GRAMS/KG OF FUEL   1.03      HC  GRAMS/MIN     .08
CO  GRAMS/KG OF FUEL    6.8      CO  GRAMS/MIN      .5
CO2 GRAMS/KG OF FUEL   3165      CO2 GRAMS/MIN    237
NOX GRAMS/KG OF FUEL  12.80      NOX GRAMS/MIN     .96
SO2 GRAMS/KG OF FUEL   5.14      SO2 GRAMS/MIN     .39
```

## TABLE G-21. HC, CO, NO$_x$ AND FUEL RESULTS
## MERCEDES 300D

| Test | Date | Emission Rate, g/km HC | CO | NO$_x$ | Fuel Cons 1/100 km | Fuel Econ. mpg |
|---|---|---|---|---|---|---|
| 1975 FTP | 11-12-75 | 0.11 | 0.49 | 1.09 | 9.37 | 25.10 |
| | 11-13-75 | 0.09 | 0.54 | 1.07 | 9.96 | 23.62 |
| | 11-14-75 | 0.09 | 0.55 | 1.04 | 10.36 | 22.70 |
| | Average | 0.10 | 0.53 | 1.07 | 9.90 | 23.80 |
| FTP Cold | 11-12-75 | 0.12 | 0.54 | 1.14 | 10.05 | 23.40 |
| | 11-13-75 | 0.08 | 0.57 | 1.10 | 10.47 | 22.46 |
| | 11-14-75 | 0.09 | 0.55 | 1.07 | 11.08 | 21.23 |
| | Average | 0.10 | 0.55 | 1.10 | 10.53 | 22.36 |
| FTP Hot | 11-12-75 | 0.08 | 0.43 | 0.99 | 8.34 | 28.20 |
| | 11-13-75 | 0.08 | 0.47 | 1.00 | 8.83 | 26.64 |
| | 11-14-75 | 0.12 | 0.49 | 0.87 | 8.46 | 27.80 |
| | Average | 0.09 | 0.46 | 0.95 | 8.54 | 27.54 |
| FET | 11-12-75 | 0.06 | 0.35 | 1.09 | 7.68 | 30.63 |
| | 11-13-75 | 0.06 | 0.38 | 1.00 | 8.09 | 29.08 |
| | 11-14-75 | 0.06 | 0.36 | 0.87 | 7.74 | 30.39 |
| | Average | 0.06 | 0.36 | 0.99 | 7.84 | 30.03 |
| SET | 11-12-75 | 0.06 | 0.37 | 1.14 | 8.13 | 28.93 |
| | 11-13-75 | 0.07 | 0.40 | 0.98 | 8.13 | 29.10 |
| | 11-14-75 | 0.12 | 0.41 | 0.81 | 7.90 | 29.78 |
| | Average | 0.08 | 0.39 | 0.98 | 8.05 | 29.27 |

```
                         TABLE G-22.                    VEHICLE EMISSION RESULTS  - 1975 FTP
                              1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 1         DATE 11/12/75                    MFGR. CODE    OM617            YR. 1975
VEHICLE MODEL  MERCEDES 300D LA          ENGINE   3.00 LITRE 5 CYL.       TEST WT.   1814 KG             ROAD LOAD   8.4 KW
TEST TYPE  -4 COLD CONT. HC              COMMENTS  3 BAG

BAROMETER 748.54 MM OF HG.                                            WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.    17.8 DEG. C                                          ABS. HUMIDITY   7.2 MILLIGRAMS/KG
REL. HUMIDITY      56 PCT.
EXHAUST EMISSIONS
                                                                      BLOWER INLET PRESS., G1 139.7 MM. H2O
    BLOWER DIF. PRESS., G2, 165.1 MM. H2O                             BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                         1              2              3
    BLOWER REVOLUTIONS                            5470           9357           5483
    HC    SAMPLE  METER READING/SCALE            14.5/2         11.6/2         13.0/2
    HC    SAMPLE  PPM                              29             23             26
    HC    BACKGRD METER READING/SCALE             3.0/2          1.5/2          7.5/2
    HC    BACKGRD PPM                              6              3             15
    CO    SAMPLE  METER READING/SCALE            35.1/*         22.8/*         31.1/*
    CO    SAMPLE  PPM                              66             43             59
    CO    BACKGRD METER READING/SCALE              .7/*           .3/*          9.5/*
    CO    BACKGRD PPM                              1              1             18
    CO2   SAMPLE  METER READING/SCALE            71.6/2         43.5/2         62.2/2
    CO2   SAMPLE  PERCENT                        2.18           1.25           1.86
    CO2   BACKGRD METER READING/SCALE             2.5/2          3.5/2          9.5/2
    CO2   BACKGRD PERCENT                          .07            .09            .25
    NOX   SAMPLE  METER READING/SCALE            31.9/3         19.0/3         29.2/3
    NOX   SAMPLE  PPM                            95.7           57.0           87.6
    NOX   BACKGRD METER READING/SCALE              .8/3          1.0/3          3.0/3
    NOX   BACKGRD PPM                             2.4            3.0            9.0

    HC    CONCENTRATION PPM                        24             20             13
    CO    CONCENTRATION PPM                        61             41             40
    CO2   CONCENTRATION PCT                      2.13           1.16           1.64
    NOX   CONCENTRATION PPM                      93.7           54.3           79.9
    HC    MASS GRAMS                              .59            .87            .33
    CO    MASS GRAMS                             3.05           3.50           2.01
    CO2   MASS GRAMS                          1676.76        1569.46        1293.92
    NOX   MASS GRAMS                             6.88           6.83           5.88

    WEIGHTED MASS HC        .11 GRAMS/KILOMETRE
    WEIGHTED MASS CO        .44 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    250.92 GRAMS/KILOMETRE
    WEIGHTED MASS NOX      1.09 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  9.37 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =    159.2 STD. CU. METRES
```

```
                       TABLE G-23.              VEHICLE EMISSION RESULTS - 1975 FTP
                                 1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 2           DATE 11/13/75                   MFGR. CODE   OM617              YR. 1975
VEHICLE MODEL  MERCEDES 300D LA            ENGINE    3.00 LITRE 5 CYL.     TEST WT.   1814 KG              ROAD LOAD   8.4 KW
TEST TYPE  -4 COLD CONT.HC                 COMMENTS  3 BAG

BAROMETER 751.08 MM OF HG.                                               WET BULB TEMP  14.4 DEG. C
DRY BULB TEMP.    24.4 DEG. C                                             ABS. HUMIDITY   6.1 MILLIGRAMS/KG
REL. HUMIDITY      32 PCT.
EXHAUST EMISSIONS

                                                                         BLOWER INLET PRESS., G1 139.7 MM. H2O
    BLOWER DIF. PRESS., G2, 190.5 MM. H2O                                BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                      1               2               3
    BLOWER REVOLUTIONS                        7546           12896            7656
    HC    SAMPLE  METER READING/SCALE       11.2/2           8.9/2          11.1/2
    HC    SAMPLE  PPM                           22              18              22
    HC    BACKGRD METER READING/SCALE        6.5/2           3.5/2           6.0/2
    HC    BACKGRD PPM                           13               7              12
    CO    SAMPLE  METER READING/SCALE       27.4/*          17.8/*          30.6/*
    CO    SAMPLE  PPM                           52              34              58
    CO    BACKGRD METER READING/SCALE        1.9/*            .8/*          10.3/*
    CO    BACKGRD PPM                            4               2              20
    CO2   SAMPLE  METER READING/SCALE       56.2/2          33.7/2          48.2/2
    CO2   SAMPLE  PERCENT                     1.66             .95            1.39
    CO2   BACKGRD METER READING/SCALE        2.2/2           2.1/2           3.5/2
    CO2   BACKGRD PERCENT                      .06             .06             .09
    NOX   SAMPLE  METER READING/SCALE       70.7/2          40.9/2          63.9/2
    NOX   SAMPLE  PPM                         70.7            40.9            63.9
    NOX   BACKGRD METER READING/SCALE        2.1/2           1.8/2           1.7/2
    NOX   BACKGRD PPM                          2.1             1.8             1.7

    HC    CONCENTRATION PPM                     11              11              11
    CO    CONCENTRATION PPM                     46              31              38
    CO2   CONCENTRATION PCT                   1.60             .89            1.31
    NOX   CONCENTRATION PPM                   68.9            39.2            62.4
    HC    MASS GRAMS                           .37             .65             .39
    CO    MASS GRAMS                          3.18            3.68            2.66
    CO2   MASS GRAMS                       1733.50         1650.73         1438.67
    NOX   MASS GRAMS                          6.72            6.54            6.17

    WEIGHTED MASS HC        .04 GRAMS/KILOMETRE
    WEIGHTED MASS CO        .54 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    266.52 GRAMS/KILOMETRE
    WEIGHTED MASS NOX      1.07 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  9.96 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   218.8 STD. CU. METRES
```

```
                     TABLE G-24.            VEHICLE EMISSION RESULTS - 1975 FTP
                        1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.            TEST NO. 3       DATE 11/14/75                   MFGR. CODE OM617          YR. 1975
VEHICLE MODEL  MERCEDES 300D LA      ENGINE   3.00 LITRE 5 CYL.      TEST WT.   1814 KG        ROAD LOAD    8.4 KW
TEST TYPE  -4 COLD CONT. HC          COMMENTS  3 BAG

BAROMETER 748.79 MM OF HG.                                          WET BULB TEMP  11.7 DEG. C
DRY BULB TEMP.    23.3 DEG. C                                        ABS. HUMIDITY   3.7 MILLIGRAMS/KG
REL. HUMIDITY      21 PCT.
EXHAUST EMISSIONS
                                                                    BLOWER INLET PRESS., G1 241.3 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                           BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                         1               2               3
    BLOWER REVOLUTIONS                            7527           12897            7513
    HC    SAMPLE  METER READING/SCALE            12.7/2           9.9/2          12.8/2
    HC    SAMPLE  PPM                              25              20              26
    HC    BACKGRD METER READING/SCALE             5.5/2           5.5/2           3.5/2
    HC    BACKGRD PPM                              11              11               7
    CO    SAMPLE  METER READING/SCALE            28.5/*          19.6/*          24.0/*
    CO    SAMPLE  PPM                              54              37              45
    CO    BACKGRD METER READING/SCALE             6.3/*            .7/*           2.1/*
    CO    BACKGRD PPM                              12               1               4
    CO2   SAMPLE  METER READING/SCALE            58.8/2          38.4/2          48.5/2
    CO2   SAMPLE  PERCENT                         1.74            1.09            1.40
    CO2   BACKGRD METER READING/SCALE              .8/2           3.6/2           3.0/2
    CO2   BACKGRD PERCENT                          .02             .09             .08
    NOX   SAMPLE  METER READING/SCALE            71.4/2          47.0/2          62.3/2
    NOX   SAMPLE  PPM                             71.4            47.0            62.3
    NOX   BACKGRD METER READING/SCALE             2.7/2           1.5/2           1.4/2
    NOX   BACKGRD PPM                              2.7             1.5             1.4

    HC    CONCENTRATION PPM                        16              10              19
    CO    CONCENTRATION PPM                        41              35              40
    CO2   CONCENTRATION PCT                       1.72            1.00            1.33
    NOX   CONCENTRATION PPM                       69.1            45.6            61.0
    HC    MASS GRAMS                               .52             .55             .63
    CO    MASS GRAMS                              2.73            3.95            2.66
    CO2   MASS GRAMS                           1795.37         1785.70         1386.49
    NOX   MASS GRAMS                              6.08            6.88            5.36

    WEIGHTED MASS HC         .04 GRAMS/KILOMETRE
    WEIGHTED MASS CO         .55 GRAMS/KILOMETRE
    WEIGHTED MASS CO2     272.44 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       1.04 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION = 10.36 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =    210.2 STD. CU. METRES
```

```
         TABLE  G-25.  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE  - SET
                               VEHICLE NUMBER

DATE 11/12/75                  TIME    -0 HRS.        TEST NO.  1
MODEL  1975 MERCEDES 300D SET-7 CONT. HC              ENGINE 3.0 LITRE    5 CYL.
DRIVER   BP                    TEST WT.  1814 KG.     GVW    0 KG
WET BULB TEMP  17 C            DRY BULB TEMP  21 C    REL. HUM.  68.0 PCT
SPEC. HUM.  10.8 GRAM/KG       BARO.  748.5 MM  HG.   MEASURED FUEL  0.00 KG

  RUN DURATION          23.44 MINUTES
  BLOWER INLET PRESS. 139.7  MM. H2O
  BLOWER DIF.  PRESS. 165.1  MM  H2O
  BLOWER INLET TEMP.     46  DEG. C
  DYNO REVOLUTIONS    31626
  BLOWER REVOLUTIONS    15179
  BLOWER CU. CM /REV.  8696

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE                 11.5/2
   HC   SAMPLE  PPM                                   23
   HC   BACKGRD METER READING/SCALE                  2.0/2
   HC   BACKGRD PPM                                    4
   CO   SAMPLE  METER READING/SCALE                 39.5/*
   CO   SAMPLE  PPM                                   74
   CO   BACKGRD METER READING/SCALE                  6.5/*
   CO   BACKGRD PPM                                   12
   CO2  SAMPLE  METER READING/SCALE                 73.0/2
   CO2  SAMPLE  PERCENT                             2.23
   CO2  BACKGRD METER READING/SCALE                  2.7/2
   CO2  BACKGRD PERCENT                              .07
   NOX  SAMPLE  METER READING/SCALE                 37.3/3
   NOX  SAMPLE  PPM                                111.9
   NOX  BACKGRD METER READING/SCALE                  .9/3
   NOX  BACKGRD PPM                                  2.7
   SO2  SAMPLE METER READING/SCALE                 40.8/*
   SO2  SAMPLE  PPM                                 10.2
   SO2  BACKGRD METER READING/SCALE                  .5/*
   SO2  BACKGRD PPM                                   .1

   HC   CONCENTRATION PPM                             20
   CO   CONCENTRATION PPM                             59
   CO2  CONCENTRATION PCT                           2.17
   NOX  CONCENTRATION PPM                          109.7
   SO2  COCENTRATION PPM                           10.1
   HC   MASS (GRAMS)                                1.34
   CO   MASS (GRAMS)                                8.15
   CO2  MASS (GRAMS)                             4708.65
   NOX  MASS (GRAMS)                               24.75
   SO2  MASS (GRAMS)                                3.25

 HC   GRAMS/KILOMETRE        .06
 CO   GRAMS/KILOMETHE        .37
 CO2  GRAMS/KILOMETRE     217
 NOX  GRAMS/KILOMETRE       1.14
 SO2  GRAMS/KILOMETRE        .15

 HC   GRAMS/KG OF FUEL     .90      HC   GRAMS/MIN     .06
 CO   GRAMS/KG OF FUEL     5.5      CO   GRAMS/MIN     .3
 CO2  GRAMS/KG OF FUEL    3167      CO2  GRAMS/MIN    201
 NOX  GRAMS/KG OF FUEL   16.65      NOX  GRAMS/MIN    1.06
 SO2  GRAMS/KG OF FUEL    2.18      SO2  GRAMS/MIN     .14
```

# TABLE G-26. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET VEHICLE NUMBER

```
DATE 11/13/75                      TIME  1220 HRS.         TEST NO.  2
MODEL  1975 MERCEDES 300D SET-7 CONT,HC                    ENGINE 3.0 LITRE I  5 CYL.
DRIVER   BP                        TEST WT.  1814  KG.     GVW    0 KG
WET BULB TEMP  14 C                DRY BULB TEMP  24 C     REL. HUM.  31.7 PCT
SPEC. HUM.   6.1 GRAM/KG           BARO.  751.1 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION             23.32 MINUTES
  BLOWER INLET PRESS. 139.7  MM. H2O
  BLOWER DIF.  PRESS. 190.5  MM  H2O
  BLOWER INLET TEMP.     48  DEG. C
  DYNO REVOLUTIONS     31513
  BLOWER REVOLUTIONS    20836
  BLOWER CU. CM /REV.  8544

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE                     9.1/2
   HC  SAMPLE  PPM                                      18
   HC  BACKGRD METER READING/SCALE                     1.5/2
   HC  BACKGRD PPM                                       3
   CO  SAMPLE  METER READING/SCALE                    27.3/*
   CO  SAMPLE  PPM                                      52
   CO  BACKGRD METER READING/SCALE                     1.5/*
   CO  BACKGRD PPM                                       3
   CO2 SAMPLE  METER READING/SCALE                    56.3/2
   CO2 SAMPLE  PERCENT                                1.66
   CO2 BACKGRD METER READING/SCALE                     2.1/2
   CO2 BACKGRD PERCENT                                 .06
   NOX SAMPLE  METER READING/SCALE                    27.4/3
   NOX SAMPLE  PPM                                    82.2
   NOX BACKGRD METER READING/SCALE                      .6/3
   NOX BACKGRD PPM                                     1.8
   SO2 SAMPLE METER READING/SCALE                     49.2/*
   SO2 SAMPLE  PPM                                    12.3
   SO2 BACKGRD METER READING/SCALE                      .7/*
   SO2 BACKGRD PPM                                      .2

   HC  CONCENTRATION PPM                                15
   CO  CONCENTRATION PPM                                47
   CO2 CONCENTRATION PCT                              1.61
   NOX CONCENTRATION PPM                              80.6
   SO2 COCENTRATION PPM                              12.2
   HC  MASS (GRAMS)                                   1.42
   CO  MASS (GRAMS)                                   8.69
   CO2 MASS (GRAMS)                                4704.68
   NOX MASS (GRAMS)                                  21.27
   SO2 MASS (GRAMS)                                   5.27

HC  GRAMS/KILOMETRE       .07
CO  GRAMS/KILOMETRE       .40
CO2 GRAMS/KILOMETRE   216
NOX GRAMS/KILOMETRE       .98
SO2 GRAMS/KILOMETRE       .24

HC  GRAMS/KG OF FUEL    .96      HC  GRAMS/MIN     .06
CO  GRAMS/KG OF FUEL    5.8      CO  GRAMS/MIN     .4
CO2 GRAMS/KG OF FUEL   3166      CO2 GRAMS/MIN    202
NOX GRAMS/KG OF FUEL  14.31      NOX GRAMS/MIN     .91
SO2 GRAMS/KG OF FUEL   3.55      SO2 GRAMS/MIN     .23
```

## TABLE G-27. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
## VEHICLE NUMBER

```
DATE 11/14/75                TIME    -0 HRS.        TEST NO.  3
MODEL  1975 MERCEDES 300D SET-7 CONT. HC            ENGINE 3.0 LITRE    5 CYL.
DRIVER   BP                  TEST WT.  1814  KG.    GVW    0 KG
WET BULB TEMP  12 C          DRY BULB TEMP  24 C    REL. HUM.  18.7 PCT
SPEC. HUM.   3.5 GRAM/KG     BARO.  748.8 MM  HG.   MEASURED FUEL  0.00 KG

  RUN DURATION          23.33 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H20
  BLOWER DIF.  PRESS. 317.5  MM  H20
  BLOWER INLET TEMP.     43  DEG. C
  DYNO REVOLUTIONS    31556
  BLOWER REVOLUTIONS    20813
  BLOWER CU. CM /REV.  8427

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE               18.5/2
   HC  SAMPLE  PPM                                 37
   HC  BACKGRD METER READING/SCALE                5.0/2
   HC  BACKGRD PPM                                 10
   CO  SAMPLE  METER READING/SCALE               29.9/*
   CO  SAMPLE  PPM                                 56
   CO  BACKGRD METER READING/SCALE                3.5/*
   CO  BACKGRD PPM                                  7
   CO2 SAMPLE  METER READING/SCALE               56.5/2
   CO2 SAMPLE  PERCENT                           1.67
   CO2 BACKGRD METER READING/SCALE                3.2/2
   CO2 BACKGRD PERCENT                            .08
   NOX SAMPLE  METER READING/SCALE               26.4/3
   NOX SAMPLE  PPM                               79.2
   NOX BACKGRD METER READING/SCALE                2.3/3
   NOX BACKGRD PPM                                6.9
   SO2 SAMPLE METER READING/SCALE               55.7/*
   SO2 SAMPLE  PPM                               13.9
   SO2 BACKGRD METER READING/SCALE                 .4/*
   SO2 BACKGRD PPM                                 .1

   HC  CONCENTRATION PPM                           28
   CO  CONCENTRATION PPM                           49
   CO2 CONCENTRATION PCT                         1.59
   NOX CONCENTRATION PPM                         73.2
   SO2 COCENTRATION PPM                         13.8
   HC  MASS (GRAMS)                              2.55
   CO  MASS (GRAMS)                              8.82
   CO2 MASS (GRAMS)                           4567.67
   NOX MASS (GRAMS)                             17.64
   SO2 MASS (GRAMS)                              5.89

HC  GRAMS/KILOMETRE       .12
CO  GRAMS/KILOMETRE       .41
CO2 GRAMS/KILOMETRE   210
NOX GRAMS/KILOMETRE       .81
SO2 GRAMS/KILOMETRE       .27

HC  GRAMS/KG OF FUEL   1.77     HC  GRAMS/MIN     .11
CO  GRAMS/KG OF FUEL    6.1     CO  GRAMS/MIN     .4
CO2 GRAMS/KG OF FUEL   3163     CO2 GRAMS/MIN    196
NOX GRAMS/KG OF FUEL  12.22     NOX GRAMS/MIN    .76
SO2 GRAMS/KG OF FUEL   4.08     SO2 GRAMS/MIN    .25
```

### TABLE G-28. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET VEHICLE NUMBER

```
                                  TIME    -0 HRS.          TEST NO.  1
DATE 11/12/75                     FET CONT. HC             ENGINE 3.0 LITRE     5 CYL.
MODEL  1975 MERCEDES 300D         TEST WT.   1814 KG.      GVW     0 KG
DRIVER   GP                       DRY BULB TEMP  21 C      REL. HUM.  68.0 PCT
WET BULB TEMP  17 C               BARO.  748.5 MM  HG.     MEASURED FUEL  0.00 KG
SPEC. HUM.  10.8 GRAM/KG

  RUN DURATION          12.78 MINUTES
  BLOWER INLET PRESS. 152.4  MM. H2O
  BLOWER DIF.  PRESS. 165.1  MM  H2O
  BLOWER INLET TEMP.     44  DEG. C
  DYNO REVOLUTIONS     23793
  BLOWER REVOLUTIONS     8292
  BLOWER CU. CM /REV.  8649

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE                 15.7/2
   HC   SAMPLE  PPM                                   31
   HC   BACKGRD METER READING/SCALE                  6.5/2.
   HC   BACKGRD PPM                                   13
   CO   SAMPLE  METER READING/SCALE                 47.0/*
   CO   SAMPLE  PPM                                   88
   CO   BACKGRD METER READING/SCALE                   .8/*
   CO   BACKGRD PPM                                    2
   CO2  SAMPLE  METER READING/SCALE                 43.0/2
   CO2  SAMPLE  PERCENT                             2.98
   CO2  BACKGRD METER READING/SCALE                  3.1/2
   CO2  BACKGRD PERCENT                              .08
   NOX  SAMPLE  METER READING/SCALE                 52.3/3
   NOX  SAMPLE  PPM                                156.9
   NOX  BACKGRD METER READING/SCALE                  3.3/3
   NOX  BACKGRD PPM                                  9.9
   SO2  SAMPLE METER READING/SCALE                  85.0/*
   SO2  SAMPLE  PPM                                 21.3
   SO2  BACKGRD METER READING/SCALE                  1.1/*
   SO2  BACKGRD PPM                                   .3

   HC   CONCENTRATION PPM                             21
   CO   CONCENTRATION PPM                             80
   CO2  CONCENTRATION PCT                           2.92
   NOX  CONCENTRATION PPM                          149.2
   SO2  COCENTRATION PPM                            21.0
   HC   MASS (GRAMS)                                 .79
   CO   MASS (GRAMS)                                6.02
   CO2  MASS (GRAMS)                             3469.82
   NOX  MASS (GRAMS)                               18.48
   SO2  MASS (GRAMS)                                3.71

 HC   GRAMS/KILOMETRE       .05
 CO   GRAMS/KILOMETRE       .35
 CO2  GRAMS/KILOMETRE    205
 NOX  GRAMS/KILOMETRE      1.09
 SO2  GRAMS/KILOMETRE       .22

 HC   GRAMS/KG OF FUEL      .72        HC   GRAMS/MIN      .06
 CO   GRAMS/KG OF FUEL   [illegible]   CO   GRAMS/MIN      .5
 CO2  GRAMS/KG OF FUEL   3168          CO2  GRAMS/MIN     271
 NOX  GRAMS/KG OF FUEL  16.87          NOX  GRAMS/MIN     1.45
 SO2  GRAMS/KG OF FUEL   3.38          SO2  GRAMS/MIN      .29
```

```
      TABLE G-29.  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET
                              VEHICLE NUMBER

DATE 11/13/75                TIME  1155 HRS.          TEST NO.  2
MODEL  1975 MERCEDES 300D FET CONT. HC                ENGINE 3.0 LITRE I  5 CYL.
DRIVER   BP                  TEST WT.  1814 KG.       GVW     0 KG
WET BULB TEMP  14 C          DRY BULB TEMP  24 C      REL. HUM.  31.7 PCT
SPEC. HUM.   6.1 GRAM/KG     BARO.  751.1 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION          12.77 MINUTES
  BLOWER INLET PRESS. 139.7  MM. H2O
  BLOWER DIF.  PRESS. 190.5  MM  H2O
  BLOWER INLET TEMP.      44  DEG. C
  DYNO REVOLUTIONS    23986
  BLOWER REVOLUTIONS    11437
  BLOWER CU. CM /REV.  8620

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE             15.5/2
   HC   SAMPLE  PPM                               31
   HC   BACKGRD METER READING/SCALE              6.0/2
   HC   BACKGRD PPM                               12
   CO   SAMPLE  METER READING/SCALE             38.1/*
   CO   SAMPLE  PPM                               72
   CO   BACKGRD METER READING/SCALE              4.1/*
   CO   BACKGRD PPM                                8
   CO2  SAMPLE  METER READING/SCALE             73.0/2
   CO2  SAMPLE  PERCENT                         2.23
   CO2  BACKGRD METER READING/SCALE              2.6/2
   CO2  BACKGRD PERCENT                          .07
   NOX SAMPLE  METER READING/SCALE             38.0/3
   NOX SAMPLE  PPM                            114.0
   NOX BACKGRD METER READING/SCALE              .8/3
   NOX BACKGRD PPM                              2.4
   SO2 SAMPLE METER READING/SCALE             82.1/*
   SO2 SAMPLE  PPM                            20.5
   SO2 BACKGRD METER READING/SCALE              1.9/*
   SO2 BACKGRD PPM                                .5

   HC   CONCENTRATION PPM                         21
   CO   CONCENTRATION PPM                         61
   CO2 CONCENTRATION PCT                        2.18
   NOX CONCENTRATION PPM                       112.0
   SO2 COCENTRATION PPM                         20.1
   HC   MASS (GRAMS)                            1.07
   CO   MASS (GRAMS)                            6.35
   CO2 MASS (GRAMS)                          3550.86
   NOX MASS (GRAMS)                            16.49
   SO2 MASS (GRAMS)                             4.86

HC   GRAMS/KILOMETRE       .06
CO   GRAMS/KILOMETRE       .39
CO2 GRAMS/KILOMETRE    215
NOX GRAMS/KILOMETRE      1.00
SO2 GRAMS/KILOMETRE       .30

HC   GRAMS/KG OF FUEL    .95     HC   GRAMS/MIN     .08
CO   GRAMS/KG OF FUEL    5.7     CO   GRAMS/MIN      .5
CO2 GRAMS/KG OF FUEL   3167     CO2 GRAMS/MIN     278
NOX GRAMS/KG OF FUEL  14.71     NOX GRAMS/MIN    1.29
SO2 GRAMS/KG OF FUEL   4.34     SO2 GRAMS/MIN     .38
```

## TABLE G-30. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET
## VEHICLE NUMBER

```
DATE 11/14/75                 TIME    -0 HRS.         TEST NO.  3
MODEL  1975 MERCEDES 300D FET CONT. HC                ENGINE 3.0 LITRE    5 CYL.
DRIVER   BP                   TEST WT.  1814  KG.     GVW    0 KG
WET BULB TEMP  12 C           DRY BULB TEMP  24 C     REL. HUM.  18.7 PCT
SPEC. HUM.   3.5 GRAM/KG      BARO.  748.8 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION          12.77 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H20
  BLOWER DIF.  PRESS. 317.5  MM  H20
  BLOWER INLET TEMP.     43  DEG. C
  DYNO REVOLUTIONS    23894
  BLOWER REVOLUTIONS    11345
  BLOWER CU. CM /REV.  8427

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE             14.6/2
   HC  SAMPLE  PPM                                29
   HC  BACKGRD METER READING/SCALE              5.0/2
   HC  BACKGRD PPM                                10
   CO  SAMPLE  METER READING/SCALE             38.2/*
   CO  SAMPLE  PPM                                72
   CO  BACKGRD METER READING/SCALE              5.2/*
   CO  BACKGRD PPM                                10
   CO2 SAMPLE  METER READING/SCALE             72.3/2
   CO2 SAMPLE  PERCENT                         2.21
   CO2 BACKGRD METER READING/SCALE              2.2/2
   CO2 BACKGRD PERCENT                          .06
   NOX SAMPLE  METER READING/SCALE             36.7/3
   NOX SAMPLE  PPM                            110.1
   NOX BACKGRD METER READING/SCALE               .8/3
   NOX BACKGRD PPM                               2.4
   SO2 SAMPLE METER READING/SCALE             94.0/*
   SO2 SAMPLE  PPM                             23.5
   SO2 BACKGRD METER READING/SCALE               .7/*
   SO2 BACKGRD PPM                                .2

   HC  CONCENTRATION PPM                          21
   CO  CONCENTRATION PPM                          60
   CO2 CONCENTRATION PCT                        2.16
   NOX CONCENTRATION PPM                       108.1
   SO2 COCENTRATION PPM                        23.3
   HC  MASS (GRAMS)                             1.03
   CO  MASS (GRAMS)                             5.99
   CO2 MASS (GRAMS)                          3395.11
   NOX MASS (GRAMS)                            14.27
   SO2 MASS (GRAMS)                             5.44

HC  GRAMS/KILOMETRE       .06
CO  GRAMS/KILOMETRE       .36
CO2 GRAMS/KILOMETRE   206
NOX GRAMS/KILOMETRE       .87
SO2 GRAMS/KILOMETRE       .33

HC  GRAMS/KG OF FUEL    .96     HC  GRAMS/MIN    .08
CO  GRAMS/KG OF FUEL    5.6     CO  GRAMS/MIN     .5
CO2 GRAMS/KG OF FUEL   3167     CO2 GRAMS/MIN    266
NOX GRAMS/KG OF FUEL  13.31     NOX GRAMS/MIN   1.12
SO2 GRAMS/KG OF FUEL   5.07     SO2 GRAMS/MIN    .43
```

## TABLE G-31, HC, CO, $NO_x$ AND FUEL RESULTS
## PEUGEOT 204D

| | | Emission Rate, g/km | | | Fuel Cons. | Fuel Econ. |
|---|---|---|---|---|---|---|
| Test | Date | HC | CO | $NO_x$ | l/100 km | mpg |
| 1975 FTP | 11-21-75 | 0.68 | 1.03 | 0.44 | 7.05 | 35.55 |
| | 11-24-75 | 0.67 | 1.00 | 0.39 | 6.43 | 36.58 |
| | 11-25-75 | 0.72 | 1.15 | 0.43 | 6.69 | 35.47 |
| | Average | 0.69 | 1.06 | 0.42 | 6.72 | 35.86 |
| FTP Cold | 11-21-75 | 0.69 | 1.03 | 0.47 | 7.38 | 31.87 |
| | 11-24-75 | 0.69 | 1.00 | 0.40 | 6.57 | 35.80 |
| | 11-25-75 | 0.69 | 1.17 | 0.46 | 6.86 | 34.29 |
| | Average | 0.69 | 1.07 | 0.44 | 6.94 | 33.99 |
| FTP Hot | 11-21-75 | 0.69 | 1.07 | 0.41 | 6.62 | 35.53 |
| | 11-24-75 | 0.67 | 1.04 | 0.37 | 6.41 | 36.69 |
| | 11-25-75 | 0.81 | 1.14 | 0.40 | 6.59 | 35.69 |
| | Average | 0.72 | 1.08 | 0.39 | 6.54 | 35.97 |
| FET | 11-21-75 | 0.40 | 0.55 | 0.36 | 5.67 | 41.49 |
| | 11-24-75 | 0.44 | 0.54 | 0.30 | 4.91 | 47.91 |
| | 11-25-75 | 0.61 | 0.62 | 0.35 | 5.63 | 42.02 |
| | Average | 0.48 | 0.57 | 0.34 | 5.40 | 43.80 |
| SET | 11-21-75 | 0.45 | 0.67 | 0.35 | 5.75 | 40.91 |
| | 11-24-75 | 0.55 | 0.72 | 0.32 | 5.55 | 42.38 |
| | 11-25-75 | 0.61 | 0.75 | 0.33 | 5.54 | 42.46 |
| | Average | 0.54 | 0.71 | 0.33 | 5.61 | 41.91 |

```
                    TABLE G-32.              VEHICLE EMISSION RESULTS - 1975 FTP
                           1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.             TEST NO. 1          DATE 11/21/75                     MFGR. CODE    PEUGEOT                YR. 1975
VEHICLE MODEL  PEUGEOT-204D  LA          ENGINE    1.36 LITRE 4 CYL.       TEST WT.   1133 KG                ROAD LOAD    7.0 KW
TEST TYPE  -4 COLD CONT,HC               COMMENTS  3 BAG

BAROMETER 749.55 MM OF HG.                                        WET BULB TEMP  11.7 DEG. C
DRY BULB TEMP.    20.6 DEG. C                                      ABS. HUMIDITY   4.9 MILLIGRAMS/KG
REL. HUMIDITY      32 PCT.
EXHAUST EMISSIONS

                                                                  BLOWER INLET PRESS., G1 251.5 MM. H2O
    BLOWER DIF. PRESS., G2, 297.2 MM. H2O                         BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                        1             2             3
    BLOWER REVOLUTIONS                          7516         12900          7521
    HC    SAMPLE  METER READING/SCALE          28.9/3        21.0/3        27.3/3
    HC    SAMPLE  PPM                           115            84           109
    HC    BACKGRD METER READING/SCALE            .5/3          .5/3         1.2/3
    HC    BACKGRD PPM                              2             2             5
    CO    SAMPLE  METER READING/SCALE          46.1/*        36.6/*        43.4/*
    CO    SAMPLE  PPM                             87            69            82
    CO    BACKGRD METER READING/SCALE          3.1/*         1.6/*          .6/*
    CO    BACKGRD PPM                              6             3             1
    CO2   SAMPLE  METER READING/SCALE          41.8/2        25.9/2        35.8/2
    CO2   SAMPLE  PERCENT                      1.19           .71          1.01
    CO2   BACKGRD METER READING/SCALE           2.4/2         2.5/2         2.2/2
    CO2   BACKGRD PERCENT                       .06           .07           .06
    NOX   SAMPLE  METER READING/SCALE          30.5/2        19.3/2        25.9/2
    NOX   SAMPLE  PPM                          30.5          19.3          25.9
    NOX   BACKGRD METER READING/SCALE            .8/2          .6/2         1.6/2
    NOX   BACKGRD PPM                             .8            .6           1.6

    HC    CONCENTRATION PPM                     114            82           105
    CO    CONCENTRATION PPM                      78            64            78
    CO2   CONCENTRATION PCT                    1.14           .65           .96
    NOX   CONCENTRATION PPM                    29.8          18.7          24.4
    HC    MASS GRAMS                           3.71          4.60          3.42
    CO    MASS GRAMS                           5.16          7.29          5.15
    CO2   MASS GRAMS                        1182.32       1165.86        995.24
    NOX   MASS GRAMS                           2.70          2.92          2.22

    WEIGHTED MASS HC        .68 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1.03 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    185.75 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .44 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  7.05 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =    210.5 STD. CU. METRES
```

```
                          TABLE  G-33.            VEHICLE EMISSION RESULTS  - 1975 FTP
                                    1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.             TEST NO. 2         DATE 11/24/75                  MFGR. CODE   PEUGEOT            YR. 1975
VEHICLE MODEL  PEUGEOT 204D  LA         ENGINE   1.36 LITRE 4 CYL.      TEST WT.  1133  KG              ROAD LOAD    9.5 KW
TEST TYPE  -4 COLD CONT.HC              COMMENTS  3 BAG

BAROMETER 747.78 MM OF HG.                                          WET BULB TEMP  11.7 DEG. C
DRY BULB TEMP.    21.1 DEG. C                                        ABS. HUMIDITY   4.7 MILLIGRAMS/KG
REL. HUMIDITY      30 PCT.
EXHAUST EMISSIONS

                                                                    BLOWER INLET PRESS., G1 254.0 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                           BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                         1               2               3
    BLOWER REVOLUTIONS                            7543           12884            7511
    HC    SAMPLE  METER READING/SCALE            29.7/3          21.4/3          27.5/3
    HC    SAMPLE   PPM                            119              86             110
    HC    BACKGRD METER READING/SCALE            1.0/3           1.0/3           1.8/3
    HC    BACKGRD PPM                               4               4               7
    CO    SAMPLE  METER READING/SCALE            41.7/*          34.8/*          40.9/*
    CO    SAMPLE   PPM                             78              66              77
    CO    BACKGRD METER READING/SCALE             .4/*            .4/*            .2/*
    CO    BACKGRD PPM                               1               1               0
    CO2   SAMPLE  METER READING/SCALE            36.3/2          24.3/2          34.2/2
    CO2   SAMPLE   PERCENT                       1.02             .67             .96
    CO2   BACKGRD METER READING/SCALE             2.0/2           2.6/2           2.3/2
    CO2   BACKGRD PERCENT                         .05             .07             .06
    NOX   SAMPLE  METER READING/SCALE            25.1/2          17.8/2          23.2/2
    NOX   SAMPLE   PPM                           25.1            17.8            23.2
    NOX   BACKGRD METER READING/SCALE             .8/2            .9/2           1.0/2
    NOX   BACKGRD PPM                              .8              .9             1.0

    HC    CONCENTRATION PPM                       115              82             103
    CO    CONCENTRATION PPM                        75              63              74
    CO2   CONCENTRATION PCT                       .98             .60             .90
    NOX   CONCENTRATION PPM                      24.4            16.9            22.3
    HC    MASS GRAMS                             3.75            4.56            3.36
    CO    MASS GRAMS                             4.97            7.14            4.88
    CO2   MASS GRAMS                          1015.01         1072.38          936.97
    NOX   MASS GRAMS                             2.20            2.61            2.00

    WEIGHTED MASS HC        .67 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1.00 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    169.24 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .34 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION =  6.43 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =   209.7 STD. CU. METRES
```

```
                    TABLE  G-34.              VEHICLE EMISSION RESULTS - 1975 FTP
                           1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.            TEST NO. 3           DATE 11/25/75                  MFGR. CODE   PEUGEOT                YR. 1975
VEHICLE MODEL  PEUGEOT 204D LA-          ENGINE   1.36 LITRE 4 CYL.     TEST WT.  1133. KG                  ROAD LOAD    7.0 KW
TEST TYPE  4 COLD CONT.HC                COMMENTS  3 BAG

BAROMETER 743.71 MM OF HG.                                              WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.    16.7 DEG. C                                            ABS. HUMIDITY   7.7 MILLIGRAMS/KG
REL. HUMIDITY      64 PCT.
EXHAUST EMISSIONS

                                                                        BLOWER INLET PRESS., G1 248.9 MM. H2O
   BLOWER DIF. PRESS., G2, 247.2 MM. H2O                                BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                       1              2              3
   BLOWER REVOLUTIONS                          7850           12912          7523
   HC    SAMPLE  METER READING/SCALE           27.[illegible]   24.3/3         33.5/3
   HC    SAMPLE  PPM                           11[illegible]     97             134
   HC    BACKGRD METER READING/SCALE            2.5/3          2.2/3          3.5/3
   HC    BACKGRD PPM                            10              9             14
   CO    SAMPLE  METER READING/SCALE           49.1/*         43.0/*         48.7/*
   CO    SAMPLE  PPM                            92             81             91
   CO    BACKGRD METER READING/SCALE            1.9/*          2.1/*          3.9/*
   CO    BACKGRD PPM                             4              4              7
   CO2   SAMPLE  METER READING/SCALE           38.6/2         24.7/2         36.1/2
   CO2   SAMPLE  PERCENT                       1.09            .68           1.02
   CO2   BACKGRD METER READING/SCALE            2.9/2          2.9/2          2.0/2
   CO2   BACKGRD PERCENT                        .08            .08            .05
   NOX   SAMPLE  METER READING/SCALE           31.9/2         17.7/2         24.5/2
   NOX   SAMPLE  PPM                           31.9           17.7           24.5
   NOX   BACKGRD METER READING/SCALE            3.8/2          1.8/2          1.0/2
   NOX   BACKGRD PPM                            3.8            1.8            1.0

   HC    CONCENTRATION PPM                      102             89            121
   CO    CONCENTRATION PPM                       85             74             81
   CO2   CONCENTRATION PCT                      1.02            .61            .97
   NOX   CONCENTRATION PPM                      28.4           16.0           23.6
   HC    MASS GRAMS                             3.43           4.95           3.92
   CO    MASS GRAMS                             5.78           8.35           5.30
   CO2   MASS GRAMS                          1100.62        1077.67        1001.88
   NOX   MASS GRAMS                             2.89           2.69           2.31

   WEIGHTED MASS HC        .72 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.15 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    175.84 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .43 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION =  6.69 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =   211.2 STD. CU. METRES
```

```
          TABLE  G-35.  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE  - SET
                               VEHICLE NUMBER

DATE 11/21/75                TIME     -0 HRS.           TEST NO.  1
MODEL  1975 PEUGEOT 204D  SET-7 CONT. HC                ENGINE 1.4 LITRE     4 CYL.
DRIVER   BP                  TEST WT.  1133 KG.         GVW    0 KG
WET BULB TEMP  12 C          DRY BULB TEMP  21 C        REL. HUM.  32.1 PCT
SPEC. HUM.   4.9 GRAM/KG    BARO.  749.6 MM  HG.        MEASURED FUEL  0.00 KG

  RUN DURATION           23.33 MINUTES
  BLOWER INLET PRESS. 256.5  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.      43  DEG. C
  DYNO REVOLUTIONS     31794
  BLOWER REVOLUTIONS     20816
  BLOWER CU. CM /REV.  8445

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE              28.8/3
   HC  SAMPLE  PPM                               115
   HC  BACKGRD METER READING/SCALE              1.7/3
   HC  BACKGRD PPM                                 7
   CO  SAMPLE  METER READING/SCALE             44.3/*
   CO  SAMPLE  PPM                                83
   CO  BACKGRD METER READING/SCALE              0.0/*
   CO  BACKGRD PPM                                 0
   CO2 SAMPLE  METER READING/SCALE             41.6/2
   CO2 SAMPLE  PERCENT                          1.19
   CO2 BACKGRD METER READING/SCALE              1.9/2
   CO2 BACKGRD PERCENT                           .05
   NOX SAMPLE  METER READING/SCALE             31.2/2
   NOX SAMPLE  PPM                              31.2
   NOX BACKGRD METER READING/SCALE              1.0/2
   NOX BACKGRD PPM                              1.0
   SO2 SAMPLE METER READING/SCALE              9.7/*
   SO2 SAMPLE  PPM                               2.4
   SO2 BACKGRD METER READING/SCALE               .4/*
   SO2 BACKGRD PPM                                .1

   HC  CONCENTRATION PPM                         109
   CO  CONCENTRATION PPM                          80
   CO2 CONCENTRATION PCT                        1.14
   NOX CONCENTRATION PPM                        30.3
   SO2 COCENTRATION PPM                         2.3
   HC  MASS (GRAMS)                             9.86
   CO  MASS (GRAMS)                            14.66
   CO2 MASS (GRAMS)                          3285.13
   NOX MASS (GRAMS)                             7.61
   SO2 MASS (GRAMS)                             1.00

HC  GRAMS/KILOMETRE        .45
CO  GRAMS/KILOMETRE        .67
CO2 GRAMS/KILOMETRE    151
NOX GRAMS/KILOMETRE        .35
SO2 GRAMS/KILOMETRE        .05

HC  GRAMS/KG OF FUEL   9.38     HC  GRAMS/MIN     .42
CO  GRAMS/KG OF FUEL   14.0     CO  GRAMS/MIN      .6
CO2 GRAMS/KG OF FUEL   3127     CO2 GRAMS/MIN     141
NOX GRAMS/KG OF FUEL   7.24     NOX GRAMS/MIN     .33
SO2 GRAMS/KG OF FUEL    .95     SO2 GRAMS/MIN     .04
```

## TABLE G 36. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
## VEHICLE NUMBER

```
DATE 11/24/75                 TIME     -0 HRS.            TEST NO.  2
MODEL  1975 PEUGEOT 204D      SET-7 CONT,HC               ENGINE 1.4 LITRE I  4 CYL.
DRIVER   BP                   TEST WT.  1133 KG.          GVW    0 KG
WET BULB TEMP  12 C           DRY BULB TEMP  21 C         REL. HUM.  29.6 PCT
SPEC. HUM.   4.7 GRAM/KG      BARO.  747.8 MM  HG.        MEASURED FUEL  0.00 KG

  RUN DURATION           23.33 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 317.5  MM  H2O
  BLOWER INLET TEMP.      43  DEG. C
  DYNO REVOLUTIONS     31292
  BLOWER REVOLUTIONS     20817
  BLOWER CU. CM /REV.  8427

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE              35.1/3
   HC  SAMPLE  PPM                               140
   HC  BACKGRD METER READING/SCALE               2.0/3
   HC  BACKGRD PPM                                 8
   CO  SAMPLE  METER READING/SCALE              48.6/*
   CO  SAMPLE  PPM                                91
   CO  BACKGRD METER READING/SCALE               1.2/*
   CO  BACKGRD PPM                                 2
   CO2 SAMPLE  METER READING/SCALE              40.3/2
   CO2 SAMPLE  PERCENT                          1.15
   CO2 BACKGRD METER READING/SCALE               1.8/2
   CO2 BACKGRD PERCENT                           .05
   NOX SAMPLE  METER READING/SCALE              29.1/2
   NOX SAMPLE  PPM                              29.1
   NOX BACKGRD METER READING/SCALE                .8/2
   NOX BACKGRD PPM                                .8
   SO2 SAMPLE METER READING/SCALE              42.1/*
   SO2 SAMPLE  PPM                              10.5
   SO2 BACKGRD METER READTNG/SCALE                .4/*
   SO2 BACKGRD PPM                                .1

   HC  CONCENTRATION PPM                         133
   CO  CONCENTRATION PPM                          86
   CO2 CONCENTRATION PCT                        1.10
   NOX CONCENTRATION PPM                        28.4
   SO2 COCENTRATION PPM                        10.4
   HC  MASS (GRAMS)                            11.96
   CO  MASS (GRAMS)                            15.64
   CO2 MASS (GRAMS)                          3162.13
   NOX MASS (GRAMS)                             7.05
   SO2 MASS (GRAMS)                             4.44

HC  GRAMS/KILOMETRE       .55
CO  GRAMS/KILOMETRE       .72
CO2 GRAMS/KILOMETRE   145
NOX GRAMS/KILOMETRE       .32
SO2 GRAMS/KILOMETRE       .20

HC  GRAMS/KG OF FUEL  11,79     HC  GRAMS/MIN    .51
CO  GRAMS/KG OF FUEL   15.4     CO  GRAMS/MIN    .7
CO2 GRAMS/KG OF FUEL   3117     CO2 GRAMS/MIN   136
NOX GRAMS/KG OF FUEL   6.95     NOX GRAMS/MIN    .30
SO2 GRAMS/KG OF FUEL   4.37     SO2 GRAMS/MIN    .19
```

## TABLE G-37. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
## VEHICLE NUMBER

```
DATE 11/25/75                  TIME     -0 HRS.          TEST NO.  3
MODEL  1975 PEUGEOT 204D SET-7 CONT.HC                   ENGINE 1.4 LITRE     4 CYL.
DRIVER   HP                    TEST WT.  1133 KG.        GVW    0 KG
WET BULB TEMP  13 C            DRY BULB TEMP  17 C       REL. HUM.  64.2 PCT
SPEC. HUM.   7.7 GRAM/KG       BARO.  743.7 MM  HG.      MEASURED FUEL  0.00 KG

  RUN DURATION            23.33 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.      45  DEG. C
  DYNO REVOLUTIONS     31243
  BLOWER REVOLUTIONS     20813
  BLOWER CU. CM /REV.  8432

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE             41.7/3
   HC   SAMPLE  PPM                              167
   HC   BACKGRD METER READING/SCALE              5.0/3
   HC   BACKGRD PPM                               20
   CO   SAMPLE  METER READING/SCALE             51.7/*
   CO   SAMPLE  PPM                               97
   CO   BACKGRD METER READING/SCALE               .9/*
   CO   BACKGRD PPM                                2
   CO2 SAMPLE  METER READING/SCALE             41.0/2
   CO2 SAMPLE  PERCENT                          1.17
   CO2 BACKGRD METER READING/SCALE              2.4/2
   CO2 BACKGRD PERCENT                           .06
   NOX SAMPLE  METER READING/SCALE             27.7/2
   NOX SAMPLE  PPM                              27.7
   NOX BACKGRD METER READING/SCALE               .8/2
   NOX BACKGRD PPM                                .8
   SO2 SAMPLE METER READING/SCALE             35.5/*
   SO2 SAMPLE  PPM                               8.9
   SO2 BACKGRD METER READING/SCALE               .4/*
   SO2 BACKGRD PPM                                .1

   HC   CONCENTRATION PPM                         144
   CO   CONCENTRATION PPM                          91
   CO2 CONCENTRATION PCT                        1.11
   NOX CONCENTRATION PPM                        27.0
   SO2 COCENTRATION PPM                          8.8
   HC   MASS (GRAMS)                           13.23
   CO   MASS (GRAMS)                           16.37
   CO2 MASS (GRAMS)                          3150.30
   NOX MASS (GRAMS)                             7.25
   SO2 MASS (GRAMS)                             3.69

HC   GRAMS/KILOMETRE       .61
CO   GRAMS/KILOMETRE       .75
CO2 GRAMS/KILOMETRE   145
NOX GRAMS/KILOMETRE       .33
SO2 GRAMS/KILOMETRE       .17

HC   GRAMS/KG OF FUEL  13.06      HC   GRAMS/MIN    .57
CO   GRAMS/KG OF FUEL   16.2      CO   GRAMS/MIN     .7
CO2 GRAMS/KG OF FUEL   3112      CO2 GRAMS/MIN    135
NOX GRAMS/KG OF FUEL   7.16      NOX GRAMS/MIN    .31
SO2 GRAMS/KG OF FUEL   3.64      SO2 GRAMS/MIN    .16
```

```
             TABLE G-38.  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE  FET
                                VEHICLE NUMBER

DATE 11/21/75                  TIME     -0 HRS.         TEST NO.  1
MODEL  1975 PEUGEOT 204D  FET CONT. HC                  ENGINE 1.4 LITRE     4 CYL.
DRIVER   EG                    TEST WT.  1133 KG.       GVW    0 KG
WET BULB TEMP  12 C            DRY BULB TEMP  21 C      REL. HUM.  32.1 PCT
SPEC. HUM.   4.9 GRAM/KG       BARO.  744.6 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION           12.74 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 302.3  MM  H2O
  BLOWER INLET TEMP.      45  DEG. C
  DYNO REVOLUTIONS    24014
  BLOWER REVOLUTIONS    11413
  BLOWER CU. CM /REV.  8439

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE                 36.5/3
   HC   SAMPLE  PPM                                  146
   HC   BACKGRD METER READING/SCALE                  3.0/3
   HC   BACKGRD PPM                                   12
   CO   SAMPLE  METER READING/SCALE                 51.2/*
   CO   SAMPLE  PPM                                   96
   CO   BACKGRD METER READING/SCALE                   .4/*
   CO   BACKGRD PPM                                    1
   CO2 SAMPLE  METER READING/SCALE                  55.4/2
   CO2 SAMPLE  PERCENT                               1.63
   CO2 BACKGRD METER READING/SCALE                   2.6/2
   CO2 BACKGRD PERCENT                                .07
   NOX SAMPLE  METER READING/SCALE                  44.5/2
   NOX SAMPLE  PPM                                  44.5
   NOX BACKGRD METER READING/SCALE                   .7/2
   NOX BACKGRD PPM                                    .7
   SO2 SAMPLE METER READING/SCALE                  74.1/*
   SO2 SAMPLE  PPM                                  18.5
   SO2 BACKGRD METER READING/SCALE                  1.0/*
   SO2 BACKGRD PPM                                    .3

   HC   CONCENTRATION PPM                             135
   CO   CONCENTRATION PPM                              91
   CO2 CONCENTRATION PCT                             1.57
   NOX CONCENTRATION PPM                             43.9
   SO2 COCENTRATION PPM                             18.3
   HC   MASS (GRAMS)                                  6.67
   CO   MASS (GRAMS)                                  9.07
   CO2 MASS (GRAMS)                               2462.22
   NOX MASS (GRAMS)                                  6.01
   SO2 MASS (GRAMS)                                  4.26

 HC   GRAMS/KILOMETRE       .40
 CO   GRAMS/KILOMETRE       .55
 CO2 GRAMS/KILOMETRE   149
 NOX GRAMS/KILOMETRE       .36
 SO2 GRAMS/KILOMETRE       .26

 HC   GRAMS/KG OF FUEL   8.48      HC   GRAMS/MIN     .52
 CO   GRAMS/KG OF FUEL   11.5      CO   GRAMS/MIN      .7
 CO2 GRAMS/KG OF FUEL   3133      CO2 GRAMS/MIN     192
 NOX GRAMS/KG OF FUEL   7.65      NOX GRAMS/MIN     .47
 SO2 GRAMS/KG OF FUEL   5.42      SO2 GRAMS/MIN     .33
```

## TABLE G-39. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET
## VEHICLE NUMBER

```
DATE 11/24/75              TIME     -0 HRS.          TEST NO.  2
MODEL  1975 PEUGEOT 204D  FET CONT. HC               ENGINE 1.4 LITRE I  4 CYL.
DRIVER   HP                TEST WT.  1133 KG.        GVW    0 KG
WET BULB TEMP  12 C        DRY BULB TEMP  21 C       REL. HUM.  29.6 PCT
SPEC. HUM.    4.7 GRAM/KG  BARO.  747.8 MM  HG.      MEASURED FUEL  0.00 KG

  RUN DURATION           12.76 MINUTES
  BLOWER INLET PRESS. 248.9  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.     45  DEG. C
  DYNO REVOLUTIONS    23792
  BLOWER REVOLUTIONS    11389
  BLOWER CU. CM /REV.  8435

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE              38.7/3
   HC  SAMPLE  PPM                              155
   HC  BACKGRD METER READING/SCALE               2.0/3
   HC  BACKGRD PPM                                8
   CO  SAMPLE  METER READING/SCALE              50.3/*
   CO  SAMPLE  PPM                               44
   CO  BACKGRD METER READING/SCALE                .9/*
   CO  BACKGRD PPM                                2
   CO2 SAMPLE  METER READING/SCALE              48.0/2
   CO2 SAMPLE  PERCENT                          1.39
   CO2 BACKGRD METER READING/SCALE               1.2/2
   CO2 BACKGRD PERCENT                           .03
   NOX SAMPLE  METER READING/SCALE              37.4/2
   NOX SAMPLE  PPM                              37.4
   NOX BACKGRD METER READING/SCALE                .8/2
   NOX BACKGRD PPM                                .8
   SO2 SAMPLE METER READING/SCALE              48.7/*
   SO2 SAMPLE  PPM                              12.2
   SO2 BACKGRD METER READING/SCALE               1.0/*
   SO2 BACKGRD PPM                                .3

   HC  CONCENTRATION PPM                         147
   CO  CONCENTRATION PPM                          89
   CO2 CONCENTRATION PCT                        1.36
   NOX CONCENTRATION PPM                        36.7
   SO2 COCENTRATION PPM                        12.0
   HC  MASS (GRAMS)                             7.23
   CO  MASS (GRAMS)                             8.84
   CO2 MASS (GRAMS)                          2125.09
   NOX MASS (GRAMS)                             4.97
   SO2 MASS (GRAMS)                             2.77

HC  GRAMS/KILOMETRE       .44
CO  GRAMS/KILOMETRE       .54
CO2 GRAMS/KILOMETRE   124
NOX GRAMS/KILOMETRE       .30
SO2 GRAMS/KILOMETRE       .17

HC  GRAMS/KG OF FUEL  10.62      HC  GRAMS/MIN     .57
CO  GRAMS/KG OF FUEL   13.0      CO  GRAMS/MIN     .7
CO2 GRAMS/KG OF FUEL   3124      CO2 GRAMS/MIN    166
NOX GRAMS/KG OF FUEL   7.31      NOX GRAMS/MIN     .39
SO2 GRAMS/KG OF FUEL   4.07      SO2 GRAMS/MIN     .22
```

```
      TABLE G-40.  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE  - FET
                           VEHICLE NUMBER

DATE 11/25/75                 TIME    -0 HRS.          TEST NO.  3
MODEL  1975 PEUGEOT 204D FET CONT. HC                  ENGINE 1.4 LITRE    4 CYL.
DRIVER   BP                   TEST WT.  1133 KG.       GVW    0 KG
WET BULB TEMP  13 C           DRY BULB TEMP  17 C      REL. HUM.  64.2 PCT
SPEC. HUM.   7.7 GRAM/KG   BARO.  743.7 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION           12.77 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H20
  BLOWER DIF.  PRESS. 284.5  MM  H20
  BLOWER INLET TEMP.      44  DEG. C
  DYNO REVOLUTIONS     23839
  BLOWER REVOLUTIONS     11390
  BLOWER CU. CM /REV.  8464

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE             55.5/3
   HC   SAMPLE  PPM                              222
   HC   BACKGRD METER READING/SCALE              4.5/3
   HC   BACKGRD PPM                               18
   CO   SAMPLE  METER READING/SCALE             60.5/*
   CO   SAMPLE  PPM                              113
   CO   BACKGRD METER READING/SCALE              2.0/*
   CO   BACKGRD PPM                                4
   CO2 SAMPLE  METER READING/SCALE              55.0/2
   CO2 SAMPLE  PERCENT                          1.62
   CO2 BACKGRD METER READING/SCALE               2.5/2
   CO2 BACKGRD PERCENT                           .07
   NOX SAMPLE  METER READING/SCALE              39.9/2
   NOX SAMPLE  PPM                              39.9
   NOX BACKGRD METER READING/SCALE               1.0/2
   NOX BACKGRD PPM                               1.0
   SO2 SAMPLE METER READING/SCALE              58.4/*
   SO2 SAMPLE  PPM                              14.6
   SO2 BACKGRD METER READING/SCALE                .7/*
   SO2 BACKGRD PPM                                .2

   HC  CONCENTRATION PPM                         206
   CO  CONCENTRATION PPM                         104
   CO2 CONCENTRATION PCT                        1.56
   NOX CONCENTRATION PPM                        39.0
   SO2 COCENTRATION PPM                        14.4
   HC  MASS (GRAMS)                            10.09
   CO  MASS (GRAMS)                            10.26
   CO2 MASS (GRAMS)                          2432.01
   NOX MASS (GRAMS)                             5.77
   SO2 MASS (GRAMS)                             3.34

HC  GRAMS/KILOMETRE       .61
CO  GRAMS/KILOMETRE       .62
CO2 GRAMS/KILOMETRE   148
NOX GRAMS/KILOMETRE       .35
SO2 GRAMS/KILOMETRE       .20

HC  GRAMS/KG OF FUEL  12.94     HC  GRAMS/MIN     .79
CO  GRAMS/KG OF FUEL   13.1     CO  GRAMS/MIN      .8
CO2 GRAMS/KG OF FUEL   3117     CO2 GRAMS/MIN    190
NOX GRAMS/KG OF FUEL   7.39     NOX GRAMS/MIN     .45
SO2 GRAMS/KG OF FUEL   4.29     SO2 GRAMS/MIN     .26
```

## TABLE G-41. HC, CO, $NO_x$ AND FUEL RESULTS
## PERKINS 6-247

| Test | Date | Emission Rate, g/km | | | Fuel Cons. 1/100 km | Fuel Econ. mpg |
|---|---|---|---|---|---|---|
| | | HC | CO | $NO_x$ | | |
| 1975 FTP | 11-21-75 | 0.43 | 1.81 | 0.99 | 9.63 | 24.42 |
| | 11-24-75 | 0.43 | 1.76 | 1.01 | 9.26 | 25.40 |
| | 11-25-75 | 0.49 | 1.78 | 0.80 | 8.65 | 27.19 |
| | Average | 0.45 | 1.78 | 0.93 | 9.18 | 25.67 |
| FTP Cold | 11-21-75 | 0.51 | 1.83 | 1.03 | 9.85 | 23.88 |
| | 11-24-75 | 0.44 | 1.86 | 1.06 | 9.82 | 23.95 |
| | 11-25-75 | 0.48 | 1.90 | 0.88 | 9.44 | 24.92 |
| | Average | 0.48 | 1.86 | 0.99 | 9.70 | 24.25 |
| FTP Hot | 11-21-75 | 0.56 | 1.84 | 0.94 | 9.59 | 24.53 |
| | 11-24-75 | 0.46 | 1.73 | 0.96 | 8.89 | 26.46 |
| | 11-25-75 | 0.48 | 1.73 | 0.72 | 7.95 | 29.58 |
| | Average | 0.50 | 1.77 | 0.87 | 8.81 | 26.85 |
| FET | 11-21-75 | 0.33 | 1.43 | 1.00 | 8.68 | 27.10 |
| | 11-24-75 | 0.68 | 1.41 | 0.97 | 8.43 | 27.90 |
| | 11-25-75 | 0.70 | 1.36 | 0.84 | 7.84 | 30.00 |
| | Average | 0.57 | 1.40 | 0.94 | 8.32 | 28.33 |
| SET | 11-21-75 | 0.71 | 1.62 | 0.90 | 8.56 | 27.48 |
| | 11-24-75 | 0.68 | 1.51 | 0.88 | 8.40 | 28.00 |
| | 11-25-75 | 0.69 | 1.60 | 0.80 | 8.30 | 28.34 |
| | Average | 0.69 | 1.58 | 0.86 | 8.42 | 27.94 |

```
                    TABLE G-42.          VEHICLE EMISSION RESULTS  - 1975 FTP
                            1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.           TEST NO. 1        DATE 11/21/75                MFGR. CODE  6-247            YR. 1975
VEHICLE MODEL  IHC-PERKINS   LA      ENGINE   4.05 LITRE 6 CYL.   TEST WT.  2041  KG           ROAD LOAD    9.5 KW
TEST TYPE  -4 COLD CONT.HC           COMMENTS  3 BAG

BAROMETER 745.49 MM OF HG.                                       WET BULB TEMP  13.3 DEG. C
DRY BULB TEMP.    23.3 DEG. C                                     ABS. HUMIDITY   5.4 MILLIGRAMS/KG
REL. HUMIDITY      30 PCT.
EXHAUST EMISSIONS
                                                                 BLOWER INLET PRESS., G1 241.3 MM. H2O
   BLOWER DIF. PRESS., G2, 242.1 MM. H2O                         BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                    1              2              3
   BLOWER REVOLUTIONS                       7526           12907          7526
   HC    SAMPLE  METER READING/SCALE        25.2/3          16.0/3         26.5/2
   HC    SAMPLE  PPM                        101             64             53
   HC    BACKGRD METER READING/SCALE         3.0/3           2.0/3          2.5/3
   HC    BACKGRD PPM                         12              8             10
   CO    SAMPLE  METER READING/SCALE        88.9/*          59.3/*         85.6/*
   CO    SAMPLE  PPM                        164             111            158
   CO    BACKGRD METER READING/SCALE         1.1/*           1.4/*          1.1/*
   CO    BACKGRD PPM                          2              3              2
   CO2   SAMPLE  METER READING/SCALE        54.7/2          33.4/2         50.9/2
   CO2   SAMPLE  PERCENT                    1.61            .94            1.48
   CO2   BACKGRD METER READING/SCALE         2.8/2           2.9/2          2.3/2
   CO2   BACKGRD PERCENT                     .07             .08            .06
   NOX   SAMPLE  METER READING/SCALE        72.0/2          38.7/2         62.7/2
   NOX   SAMPLE  PPM                        72.0            38.7           62.7
   NOX   BACKGRD METER READING/SCALF         1.1/2           1.2/2          1.4/2
   NOX   BACKGRD PPM                         1.1             1.2            1.4

   HC    CONCENTRATION PPM                    90             56             44
   CO    CONCENTRATION PPM                   156            105            150
   CO2   CONCENTRATION PCT                   1.54           .87            1.43
   NOX   CONCENTRATION PPM                   71.0           37.6           61.5
   HC    MASS GRAMS                          2.94           3.15           1.44
   CO    MASS GRAMS                         10.23          11.86           9.88
   CO2   MASS GRAMS                       1600.47        1591.09        1483.05
   NOX   MASS GRAMS                          6.54           5.93           5.66

   WEIGHTED MASS HC        .43 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.81 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    254.79 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .94 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION =  9.63 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =    209.8 STD. CU. METRES
```

```
                    TABLE G-43.               VEHICLE EMISSION RESULTS  - 1975 FTP
                              1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.              TEST NO. 2
VEHICLE MODEL  IHC-PERKINS   LA        DATE 11/24/75
TEST TYPE  -4 COLD CONT.HC             ENGINE   4.05 LITRE 6 CYL.        MFGR. CODE   6-247
                                       COMMENTS  3 BAG                   TEST WT.   2041 KG              YR. 1975
                                                                                                         ROAD LOAD   9.5 KW
BAROMETER 749.30 MM OF HG.
DRY BULB TEMP.   17.2 DEG. C                                       WET BULB TEMP  14.4 DEG. C
REL. HUMIDITY     74 PCT.                                           ABS. HUMIDITY   9.2 MILLIGRAMS/KG
EXHAUST EMISSIONS


   BLOWER DIF. PRESS., G2, 317.5 MM. H2O                           BLOWER INLET PRESS., G1 266.7 MM. H2O
                                                                   BLOWER INLET TEMP.   43 DEG. C
   BAG RESULTS
   BAG NO.
   BLOWER REVOLUTIONS                                 1             2              3
   HC    SAMPLE  METER READING/SCALE                7525          12913           7525
   HC    SAMPLE  PPM                                26.1/3         13.8/3         26.4/3
   HC    BACKGRD METER READING/SCALE                 104            55            106
   HC    BACKGRD PPM                                 4.0/3          3.5/3          5.0/3
   CO    SAMPLE  METER READING/SCALE                 16            14              20
   CO    SAMPLE  PPM                                50.7/*         29.9/*         41.0/*
   CO    BACKGRD METER READING/SCALE                209            110            160
   CO    BACKGRD PPM                                 9.9/*          3.9/*          1.2/*
   CO2   SAMPLE  METER READING/SCALE                 19             13              4
   CO2   SAMPLE  PERCENT                            55.7/2         32.3/2         45.6/2
   CO2   BACKGRD METER READING/SCALE                1.64           .90            1.31
   CO2   BACKGRD PERCENT                             2.8/2          2.4/2          1.8/2
   NOX   SAMPLE  METER READING/SCALE                 .07           .06             .05
   NOX   SAMPLE  PPM                                65.9/2         36.2/2         53.3/2
   NOX   BACKGRD METER READING/SCALE                65.9           36.2           53.3
   NOX   BACKGRD PPM                                 1.9/2          1.2/2           .1/2
                                                     1.9            1.2             .1
   HC    CONCENTRATION PPM
   CO    CONCENTRATION PPM                            90             42             88
   CO2   CONCENTRATION PCT                           181             94            149
   NOX   CONCENTRATION PPM                          1.57            .84           1.27
   HC    MASS GRAMS                                 64.2           35.1           53.2
   CO    MASS GRAMS                                 2.94           2.35           2.85
   CO2   MASS GRAMS                                11.91          10.55           9.75
   NOX   MASS GRAMS                              1632.57        1502.73        1316.53
                                                    6.60           6.19           5.47
   WEIGHTED MASS HC        .43 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.76 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    244.89 GRAMS/KILOMETRE
   WEIGHTED MASS NOX      1.01 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION =  9.26 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =   204.6 STD. CU. METRES
```

TABLE G-44. VEHICLE EMISSION RESULTS - 1975 FTP
1975 LIGHT DUTY EMISSIONS TEST

UNIT NO. TEST NO. 3
VEHICLE MODEL IHC-PERKINS LA-4
TEST TYPE COLD CONT.HC

DATE 11/25/75
ENGINE 4.05 LITRE 6 CYL.
COMMENTS 3 BAG

MFGR. CODE 6-247
TEST WT. 2041 KG

YR. 1975
ROAD LOAD 9.5 KW

BAROMETER 738.12 MM OF HG.
DRY BULB TEMP. 21.7 DEG. C
REL. HUMIDITY 28 PCT.
EXHAUST EMISSIONS

WET BULB TEMP 11.7 DEG. C
ABS. HUMIDITY 4.5 MILLIGRAMS/KG

BLOWER DIF. PRESS., G2, 249.7 MM. H2O

BLOWER INLET PRESS., G1 241.3 MM. H2O
BLOWER INLET TEMP. 43 DEG. C

BAG RESULTS

| BAG NO. | 1 | 2 | 3 |
|---|---|---|---|
| BLOWER REVOLUTIONS | 7531 | 12908 | 7531 |
| HC SAMPLE METER READING/SCALE | 23.8/3 | 15.8/3 | 25.4/3 |
| HC SAMPLE PPM | 95 | 63 | 102 |
| HC BACKGRD METER READING/SCALE | 2.1/3 | 2.5/3 | 2.8/3 |
| HC BACKGRD PPM | 8 | 10 | 11 |
| CO SAMPLE METER READING/SCALE | 98.5/* | 57.7/* | 79.9/* |
| CO SAMPLE PPM | 181 | 108 | 148 |
| CO BACKGRD METER READING/SCALE | .3/* | .1/* | 5.4/* |
| CO BACKGRD PPM | 1 | 0 | 10 |
| CO2 SAMPLE METER READING/SCALE | 52.9/2 | 31.4/2 | 39.6/2 |
| CO2 SAMPLE PERCENT | 1.55 | .88 | 1.12 |
| CO2 BACKGRD METER READING/SCALE | 1.3/2 | 2.1/2 | 1.8/2 |
| CO2 BACKGRD PERCENT | .03 | .06 | .05 |
| NOX SAMPLE METER READING/SCALE | 63.4/2 | 34.5/2 | 44.7/2 |
| NOX SAMPLE PPM | 63.4 | 34.5 | 44.7 |
| NOX BACKGRD METER READING/SCALE | 1.0/2 | 1.2/2 | 1.2/2 |
| NOX BACKGRD PPM | 1.0 | 1.2 | 1.2 |
| HC CONCENTRATION PPM | 88 | 54 | 91 |
| CO CONCENTRATION PPM | 174 | 105 | 134 |
| CO2 CONCENTRATION PCT | 1.52 | .82 | 1.08 |
| NOX CONCENTRATION PPM | 62.5 | 33.4 | 43.6 |
| HC MASS GRAMS | 2.83 | 2.98 | 2.95 |
| CO MASS GRAMS | 11.28 | 11.69 | 8.72 |
| CO2 MASS GRAMS | 1557.51 | 1451.85 | 1110.63 |
| NOX MASS GRAMS | 5.55 | 5.08 | 3.87 |

| | | |
|---|---|---|
| WEIGHTED MASS HC | .44 | GRAMS/KILOMETRE |
| WEIGHTED MASS CO | 1.78 | GRAMS/KILOMETRE |
| WEIGHTED MASS CO2 | 228.27 | GRAMS/KILOMETRE |
| WEIGHTED MASS NOX | .80 | GRAMS/KILOMETRE |

CARBON BALANCE FUEL CONSUMPTION = 8.65 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW = 207.4 STD. CU. METRES

## TABLE G-45. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET
## VEHICLE NUMBER

```
DATE 11/21/75                TIME     -0 HRS.         TEST NO.  1
MODEL  1975 IHC-PERKINS FET CONT. HC                  ENGINE 4.0 LITRE I  6 CYL.
DRIVER   BP                  TEST WT.  2041 KG.       GVW    0 KG
WET BULB TEMP  13 C          DRY BULB TEMP  23 C      REL. HUM.  30.2 PCT
SPEC. HUM.   5.4 GRAM/KG     BARO.  745.5 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION          12.77 MINUTES
  BLOWER INLET PRESS. 241.3  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.      43  DEG. C
  DYNO REVOLUTIONS    23898
  BLOWER REVOLUTIONS    11391
  BLOWER CU. CM /REV.  8443

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE             29.6/3
   HC   SAMPLE  PPM                              118
   HC   BACKGRD METER READING/SCALE              2.5/3
   HC   BACKGRD PPM                               10
   CO   SAMPLE  METER READING/SCALE             58.7/*
   CO   SAMPLE  PPM                              254
   CO   BACKGRD METER READING/SCALE              1.1/*
   CO   BACKGRD PPM                                2
   CO2 SAMPLE  METER READING/SCALE              79.1/2
   CO2 SAMPLE  PERCENT                          2.46
   CO2 BACKGRD METER READING/SCALE               2.4/2
   CO2 BACKGRD PERCENT                           .06
   NOX SAMPLE  METER READING/SCALE              39.7/3
   NOX SAMPLE  PPM                             119.1
   NOX BACKGRD METER READING/SCALE               1.1/2
   NOX BACKGRD PPM                               1.1
   SO2 SAMPLE METER READING/SCALE              93.5/*
   SO2 SAMPLE  PPM                             23.4
   SO2 BACKGRD METER READING/SCALE                .4/*
   SO2 BACKGRD PPM                                .1

   HC   CONCENTRATION PPM                        110
   CO   CONCENTRATION PPM                        238
   CO2 CONCENTRATION PCT                        2.40
   NOX CONCENTRATION PPM                       118.2
   SO2 CUCENTRATION PPM                        23.3
   HC   MASS (GRAMS)                            5.42
   CO   MASS (GRAMS)                           23.65
   CO2 MASS (GRAMS)                          3770.96
   NOX MASS (GRAMS)                            16.44
   SO2 MASS (GRAMS)                             5.41

HC  GRAMS/KILOMETRE        .33
CO  GRAMS/KILOMETRE       1.43
CO2 GRAMS/KILOMETRE    229
NOX GRAMS/KILOMETRE       1.00
SO2 GRAMS/KILOMETRE        .33

HC  GRAMS/KG OF FUEL   4.50     HC  GRAMS/MIN     .42
CO  GRAMS/KG OF FUEL   19.6     CO  GRAMS/MIN     1.9
CO2 GRAMS/KG OF FUEL   3133     CO2 GRAMS/MIN     295
NOX GRAMS/KG OF FUEL  13.66     NOX GRAMS/MIN    1.29
SO2 GRAMS/KG OF FUEL   4.50     SO2 GRAMS/MIN     .42
```

```
          TABLE G-46.  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE-  FET
                              VEHICLE NUMBER

DATE 11/24/75               TIME     -0 HRS.         TEST NO.  2
MODEL  1975 HC-PERKINS      FET CONT.HC              ENGINE 4.2 LITRE    6 CYL.
DRIVER   BP                 TEST WT.  2041 KG.       GVW    0 KG
WET BULB TEMP  13 C         DRY BULB TEMP  21 C      REL. HUM.  39.5 PCT
SPEC. HUM.   6.0 GRAM/KG    BARO.  744.3 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION           12.79 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 317.5  MM  H2O
  BLOWER INLET TEMP.      44  DEG. C
  DYNO REVOLUTIONS     23864
  BLOWER REVOLUTIONS    11413
  BLOWER CU. CM /REV.  8421

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE              29.9/4
   HC   SAMPLE  PPM                              239
   HC   BACKGRD METER READING/SCALE               3.0/3
   HC   BACKGRD PPM                               12
   CO   SAMPLE  METER READING/SCALE              58.5/*
   CO   SAMPLE  PPM                              253
   CO   BACKGRD METER READING/SCALE               1.4/*
   CO   BACKGRD PPM                                4
   CO2 SAMPLE  METER READING/SCALE               77.1/2
   CO2 SAMPLE  PERCENT                           2.38
   CO2 BACKGRD METER READING/SCALE                2.8/2
   CO2 BACKGRD PERCENT                            .07
   NOX SAMPLE  METER READING/SCALE               38.0/3
   NOX SAMPLE  PPM                              114.0
   NOX BACKGRD METER READING/SCALE                1.2/2
   NOX BACKGRD PPM                                1.2
   SO2 SAMPLE METER READING/SCALE                93.3/*
   SO2 SAMPLE  PPM                               23.3
   SO2 BACKGRD METER READING/SCALE                2.4/*
   SO2 BACKGRD PPM                                 .6

   HC  CONCENTRATION PPM                          229
   CO  CONCENTRATION PPM                          235
   CO2 CONCENTRATION PCT                         2.32
   NOX CONCENTRATION PPM                        113.0
   SO2 COCENTRATION PPM                          22.8
   HC  MASS (GRAMS)                              11.28
   CO  MASS (GRAMS)                              23.30
   CO2 MASS (GRAMS)                            3641.16
   NOX MASS (GRAMS)                              15.96
   SO2 MASS (GRAMS)                               5.31

 HC  GRAMS/KILOMETRE       .68
 CO  GRAMS/KILOMETRE      1.41
 CO2 GRAMS/KILOMETRE    221
 NOX GRAMS/KILOMETRE       .97
 SO2 GRAMS/KILOMETRE       .32

 HC  GRAMS/KG OF FUEL   9.66     HC  GRAMS/MIN     .88
 CO  GRAMS/KG OF FUEL   19.9     CO  GRAMS/MIN     1.8
 CO2 GRAMS/KG OF FUEL   3117     CO2 GRAMS/MIN     285
 NOX GRAMS/KG OF FUEL  13.66     NOX GRAMS/MIN    1.25
 SO2 GRAMS/KG OF FUEL   4.54     SO2 GRAMS/MIN     .41
```

## TABLE G-47. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - FET
## VEHICLE NUMBER

```
DATE 11/25/75               TIME    -0 HRS.        TEST NO.  3
MODEL  1975 IHC-PERKINS  FEI CONT. HC              ENGINE 4.0 LITRE    6 CYL.
DRIVER   BP                 TEST WT.  2041 KG.     GVW    0 KG
WET BULB TEMP  12 C         DRY BULB TEMP  22 C    REL. HUM.  27.5 PCT
SPEC. HUM.   4.5 GRAM/KG    BARO.  738.1 MM  HG.   MEASURED FUEL  0.00 KG

  RUN DURATION           12.78 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H20
  BLOWER DIF.  PRESS. 312.4  MM  H20
  BLOWER INLET TEMP.      45  DEG. C
  DYNO REVOLUTIONS     23812
  BLOWER REVOLUTIONS     11398
  BLOWER CU. CM /REV.  8418

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE           30.8/4
   HC  SAMPLE  PPM                           247
   HC  BACKGRD METER READING/SCALE            2.5/3
   HC  BACKGRD PPM                            10
   CO  SAMPLE  METER READING/SCALE           57.0/*
   CO  SAMPLE  PPM                           244
   CO  BACKGRD METER READING/SCALE             .3/*
   CO  BACKGRD PPM                             1
   CO2 SAMPLE  METER READING/SCALE           73.3/2
   CO2 SAMPLE  PERCENT                       2.24
   CO2 BACKGRD METER READING/SCALE            2.2/2
   CO2 BACKGRD PERCENT                        .06
   NOX SAMPLE  METER READING/SCALE           35.2/3
   NOX SAMPLE  PPM                          105.6
   NOX BACKGRD METER READING/SCALE             .8/3
   NOX BACKGRD PPM                            2.4
   SO2 SAMPLE METER READING/SCALE           82.1/*
   SO2 SAMPLE  PPM                          20.5
   SO2 BACKGRD METER READING/SCALE            1.0/*
   SO2 BACKGRD PPM                             .3

   HC  CONCENTRATION PPM                     238
   CO  CONCENTRATION PPM                     231
   CO2 CONCENTRATION PCT                    2.20
   NOX CONCENTRATION PPM                   103.6
   SO2 COCENTRATION PPM                    20.3
   HC  MASS (GRAMS)                        11.50
   CO  MASS (GRAMS)                        22.49
   CO2 MASS (GRAMS)                      3380.91
   NOX MASS (GRAMS)                        13.78
   SO2 MASS (GRAMS)                         4.63

HC  GRAMS/KILOMETRE      .70
CO  GRAMS/KILOMETRE     1.36
CO2 GRAMS/KILOMETRE   205
NOX GRAMS/KILOMETRE      .84
SO2 GRAMS/KILOMETRE      .28

HC  GRAMS/KG OF FUEL  10.59     HC  GRAMS/MIN     .90
CO  GRAMS/KG OF FUEL   20.7     CO  GRAMS/MIN     1.8
CO2 GRAMS/KG OF FUEL   3112     CO2 GRAMS/MIN     265
NOX GRAMS/KG OF FUEL  12.69     NOX GRAMS/MIN    1.08
SO2 GRAMS/KG OF FUEL   4.27     SO2 GRAMS/MIN     .36
```

## TABLE G-48. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET VEHICLE NUMBER

```
DATE 11/21/75                TIME    -0 HRS.         TEST NO.  1
MODEL  1975 IHC PERKINS SET-7 CONT. HC               ENGINE 4.0 LITRE I  6 CYL.
DRIVER   BP                  TEST WT.  2041 KG.      GVW    0 KG
WET BULB TEMP  13 C          DRY BULB TEMP  23 C     REL. HUM.  30.2 PCT
SPEC. HUM.   5.4 GRAM/KG     BARO.  745.5 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION          23.32 MINUTES
  BLOWER INLET PRESS. 246.4  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.      43  DEG. C
  DYNO REVOLUTIONS     31114
  BLOWER REVOLUTIONS     20809
  BLOWER CU. CM /REV.  8443

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE            44.4/3
   HC  SAMPLE  PPM                             178
   HC  BACKGRD METER READING/SCALE             1.5/3
   HC  BACKGRD PPM                               6
   CO  SAMPLE  METER READING/SCALE            50.1/*
   CO  SAMPLE  PPM                             206
   CO  BACKGRD METER READING/SCALE              .8/*
   CO  BACKGRD PPM                               3
   CO2 SAMPLE  METER READING/SCALE            59.4/2
   CO2 SAMPLE  PERCENT                        1.76
   CO2 BACKGRD METER READING/SCALE             2.7/2
   CO2 BACKGRD PERCENT                         .07
   NOX SAMPLE  METER READING/SCALE            26.2/3
   NOX SAMPLE  PPM                            78.6
   NOX BACKGRD METER READING/SCALE              .5/3
   NOX BACKGRD PPM                             1.5
   SO2 SAMPLE METER READING/SCALE            55.7/*
   SO2 SAMPLE  PPM                            13.9
   SO2 BACKGRD METER READING/SCALE              .6/*
   SO2 BACKGRD PPM                              .1

   HC  CONCENTRATION PPM                       172
   CO  CONCENTRATION PPM                       195
   CO2 CONCENTRATION PCT                      1.70
   NOX CONCENTRATION PPM                      77.3
   SO2 CUCENTRATION PPM                      13.8
   HC  MASS (GRAMS)                          15.49
   CO  MASS (GRAMS)                          35.30
   CO2 MASS (GRAMS)                        4870.75
   NOX MASS (GRAMS)                          19.63
   SO2 MASS (GRAMS)                           5.86

HC  GRAMS/KILOMETRE       .71
CO  GRAMS/KILOMETRE      1.62
CO2 GRAMS/KILOMETRE   224
NOX GRAMS/KILOMETRE       .90
SO2 GRAMS/KILOMETRE       .27

HC  GRAMS/KG OF FUEL   9.90     HC  GRAMS/MIN     .66
CO  GRAMS/KG OF FUEL   22.6     CO  GRAMS/MIN    1.5
CO2 GRAMS/KG OF FUEL   3112     CO2 GRAMS/MIN    209
NOX GRAMS/KG OF FUEL  12.54     NOX GRAMS/MIN     .84
SO2 GRAMS/KG OF FUEL   3.75     SO2 GRAMS/MIN     .25
```

### TABLE G-49. EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
### VEHICLE NUMBER

```
DATE 11/24/75              TIME    -0 HRS.         TEST NO.  2
MODEL  1975 IHC-PERKINS    SET-7 CONT.HC           ENGINE 4.2 LITRE    6 CYL.
DRIVER   BP                TEST WT.  2041 KG.      GVW    0 KG
WET BULB TEMP  13 C        DRY BULB TEMP  21 C     REL. HUM.  39.5 PCT
SPEC. HUM.   6.0 GRAM/KG   BARO.  744.3 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION          23.33 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H20
  BLOWER DIF.  PRESS. 317.5  MM  H20
  BLOWER INLET TEMP.     44  DEG. C
  DYNO REVOLUTIONS    31421
  BLOWER REVOLUTIONS    20815
  BLOWER CU. CM /REV.  8421

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE             21.7/4
   HC  SAMPLE  PPM                              173
   HC  BACKGRD METER READING/SCALE              2.7/3
   HC  BACKGRD PPM                               11
   CO  SAMPLE  METER READING/SCALE             47.9/*
   CO  SAMPLE  PPM                              194
   CO  BACKGRD METER READING/SCALE              1.4/*
   CO  BACKGRD PPM                                4
   CO2 SAMPLE  METER READING/SCALE             58.7/2
   CO2 SAMPLE  PERCENT                         1.74
   CO2 BACKGRD METER READING/SCALE              2.9/2
   CO2 BACKGRD PERCENT                          .08
   NOX SAMPLE  METER READING/SCALE             25.2/3
   NOX SAMPLE  PPM                             75.6
   NOX BACKGRD METER READING/SCALE               .5/3
   NOX BACKGRD PPM                              1.5
   SO2 SAMPLE METER READING/SCALE             55.1/*
   SO2 SAMPLE  PPM                             13.8
   SO2 BACKGRD METER READING/SCALE              1.0/*
   SO2 BACKGRD PPM                               .2

   HC  CONCENTRATION PPM                        164
   CO  CONCENTRATION PPM                        181
   CO2 CONCENTRATION PCT                       1.67
   NOX CONCENTRATION PPM                       74.3
   SO2 COCENTRATION PPM                       13.6
   [illegible]C  MASS (GRAMS)                          14.70
   CO  MASS (GRAMS)                          32.86
   CO2 MASS (GRAMS)                        4783.62
   NOX MASS (GRAMS)                          19.13
   SO2 MASS (GRAMS)                           5.76

HC  GRAMS/KILOMETRE       .68
CO  GRAMS/KILOMETRE      1.51
CO2 GRAMS/KILOMETRE    220
NOX GRAMS/KILOMETRE       .88
SO2 GRAMS/KILOMETRE       .26

HC  GRAMS/KG OF FUEL   9.57      HC  GRAMS/MIN    .63
CO  GRAMS/KG OF FUEL   21.4      CO  GRAMS/MIN    1.4
CO2 GRAMS/KG OF FUEL   3115      CO2 GRAMS/MIN    205
NOX GRAMS/KG OF FUEL  12.46      NOX GRAMS/MIN    .82
SO2 GRAMS/KG OF FUEL   3.75      SO2 GRAMS/MIN    .25
```

```
        TABLE G-50.   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE - SET
                               VEHICLE NUMBER

DATE 11/25/75                  TIME    -0 HRS.         TEST NO.  3
MODEL  1975 IHC-PERKINS SET-7 CONT. HC                 ENGINE 4.0 LITRE    6 CYL.
DRIVER   BP                    TEST WT.  2041 KG.      GVW    0 KG
WET BULB TEMP  12 C            DRY BULB TEMP  22 C     REL. HUM.  27.5 PCT
SPEC. HUM.    4.5 GRAM/KG      BARO.  738.1 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION          23.32 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.     45  DEG. C
  DYNO REVOLUTIONS    31398
  BLOWER REVOLUTIONS    20809
  BLOWER CU. CM /REV.  8429

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE               21.8/4
   HC  SAMPLE  PPM                                174
   HC  BACKGRD METER READING/SCALE                1.5/3
   HC  BACKGRD PPM                                  6
   CO  SAMPLE  METER READING/SCALE               49.9/*
   CO  SAMPLE  PPM                                205
   CO  BACKGRD METER READING/SCALE                 .5/*
   CO  BACKGRD PPM                                  2
   CO2 SAMPLE  METER READING/SCALE               58.4/2
   CO2 SAMPLE  PERCENT                           1.73
   CO2 BACKGRD METER READING/SCALE                2.2/2
   CO2 BACKGRD PERCENT                            .06
   NOX SAMPLE  METER READING/SCALE               24.5/3
   NOX SAMPLE  PPM                               73.5
   NOX BACKGRD METER READING/SCALE                 .6/3
   NOX BACKGRD PPM                                1.8
   SO2 SAMPLE METER READING/SCALE               59.3/*
   SO2 SAMPLE  PPM                              14.8
   SO2 BACKGRD METER READING/SCALE                 .6/*
   SO2 BACKGRD PPM                                 .1

   HC  CONCENTRATION PPM                          169
   CO  CONCENTRATION PPM                          195
   CO2 CONCENTRATION PCT                         1.68
   NOX CONCENTRATION PPM                         71.9
   SO2 COCENTRATION PPM                         14.7
   HC  MASS (GRAMS)                             14.90
   CO  MASS (GRAMS)                             34.69
   CO2 MASS (GRAMS)                           4721.95
   NOX MASS (GRAMS)                             17.49
   SO2 MASS (GRAMS)                              6.14

HC  GRAMS/KILOMETRE       .69
CO  GRAMS/KILOMETRE      1.60
CO2 GRAMS/KILOMETRE    217
NOX GRAMS/KILOMETRE       .80
SO2 GRAMS/KILOMETRE       .28

HC  GRAMS/KG OF FUEL   9.81      HC  GRAMS/MIN     .64
CO  GRAMS/KG OF FUEL   22.9      CO  GRAMS/MIN     1.5
CO2 GRAMS/KG OF FUEL   3111      CO2 GRAMS/MIN     202
NOX GRAMS/KG OF FUEL  11.53      NOX GRAMS/MIN     .75
SO2 GRAMS/KG OF FUEL   4.05      SO2 GRAMS/MIN     .26
```

# APPENDIX H

# PARTICULATE EMISSION RATES
# FOR
# FIVE LD DIESEL VEHICLES

## TABLE H-1. PARTICULATE EMISSION RATES - MERCEDES 220D COMPREX

47mm Size Filters

| | | Fiberglass | | | | Fluoropore | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test | Date | g/test | g/hr | g/kg fuel | g/km | g/test | g/hr | g/kg fuel | g/km |
| FTP | 8-26-75 | 4.97 | 12.94 | 5.15 | 0.411 | 4.70 | 12.23 | 4.87 | 0.389 |
| Cold | 8-27-75 | 5.00 | 12.53 | 5.19 | 0.415 | 4.77 | 12.42 | 4.95 | 0.395 |
| | 8-28-75 | 4.91 | 12.78 | 5.09 | 0.407 | 4.29 | 11.17 | 4.44 | 0.355 |
| Average | | 4.96 | 12.75 | 5.14 | 0.411 | 4.59 | 11.94 | 4.75 | 0.379 |
| FTP | 8-26-75 | 4.10 | 10.66 | 4.80 | 0.340 | 3.86 | 10.06 | 4.53 | 0.320 |
| Hot | 8-27-75 | 4.37 | 11.37 | 5.13 | 0.362 | 4.02 | 10.48 | 4.71 | 0.333 |
| | 8-28-75 | 4.25 | 11.05 | 4.90 | 0.346 | 4.12 | 10.72 | 4.83 | 0.341 |
| Average | | 4.24 | 11.03 | 4.94 | 0.349 | 4.00 | 10.42 | 4.69 | 0.331 |
| 1975 | 8-26-75 | 4.47 | 11.64 | 4.95 | 0.370 | 4.22 | 10.99 | 4.68 | 0.350 |
| FTP | 8-27-75 | 4.64 | 11.87 | 5.16 | 0.385 | 4.34 | 11.31 | 4.81 | 0.360 |
| | 8-28-75 | 4.53 | 11.79 | 4.98 | 0.372 | 4.19 | 10.91 | 4.66 | 0.347 |
| Average | | 4.54 | 11.76 | 5.03 | 0.375 | 4.25 | 11.07 | 4.71 | 0.352 |
| FET | 8-27-75 | 3.96 | 18.64 | 4.02 | 0.237 | 3.93 | 18.49 | 3.99 | 0.236 |
| SET | 8-27-75 | 5.78 | 14.87 | 4.22 | 0.265 | 5.36 | 13.81 | 3.93 | 0.247 |

## TABLE H-2. PARTICULATE EMISSION RATES - MERCEDES 240D

47mm Size Filters

| | | Fiberglass | | | | Fluoropore | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test | Date | $\frac{g}{test}$ | $\frac{g}{hr}$ | $\frac{g}{kg\ fuel}$ | $\frac{g}{km}$ | $\frac{g}{test}$ | $\frac{g}{hr}$ | $\frac{g}{kg\ fuel}$ | $\frac{g}{km}$ |
| FTP | 8-22-75 | 3.72 | 9.67 | 3.84 | 0.306 | 3.48 | 9.06 | 3.60 | 0.286 |
| Cold | 8-29-75 | 3.92 | 10.21 | 4.07 | 0.324 | 3.98 | 10.35 | 4.13 | 0.328 |
| | 9-2-75 | 3.94 | 10.28 | 4.09 | 0.326 | 3.68 | 9.57 | 3.82 | 0.304 |
| Average | | 3.86 | 10.05 | 4.00 | 0.319 | 3.71 | 9.66 | 3.85 | 0.306 |
| FTP | 8-22-75 | 3.49 | 9.08 | 3.99 | 0.288 | 3.20 | 8.34 | 3.68 | 0.265 |
| Hot | 8-29-75 | 3.29 | 8.57 | 3.77 | 0.272 | 3.18 | 8.29 | 3.65 | 0.263 |
| | 9-2-75 | 3.53 | 9.20 | 4.04 | 0.292 | 3.27 | 8.51 | 3.74 | 0.269 |
| Average | | 3.44 | 8.95 | 3.93 | 0.284 | 3.22 | 8.38 | 3.69 | 0.266 |
| 1975 | 8-22-75 | 3.59 | 9.33 | 3.93 | 0.295 | 3.32 | 8.65 | 3.64 | 0.274 |
| FTP | 8-29-75 | 3.56 | 9.28 | 3.90 | 0.294 | 3.52 | 9.18 | 3.87 | 0.291 |
| | 9-2-75 | 3.71 | 9.66 | 4.06 | 0.306 | 3.45 | 8.97 | 3.77 | 0.284 |
| Average | | 3.62 | 9.42 | 3.96 | 0.298 | 3.43 | 8.93 | 3.76 | 0.283 |
| FET | 8-22-75 | 3.34 | 15.71 | 3.47 | 0.202 | 3.00 | 14.15 | 3.13 | 0.183 |
| | 8-29-75 | 3.04 | 14.42 | 3.15 | 0.184 | 2.90 | 13.67 | 3.01 | 0.176 |
| | 9-2-75 | 3.30 | 15.68 | 3.42 | 0.199 | 2.81 | 13.24 | 2.90 | 0.170 |
| Average | | 3.23 | 15.27 | 3.35 | 0.195 | 2.90 | 13.68 | 3.01 | 0.176 |
| SET | 8-22-75 | 4.66 | 12.00 | 3.47 | 0.214 | 4.39 | 11.30 | 3.26 | 0.201 |
| | 8-29-75 | 4.84 | 12.47 | 3.61 | 0.222 | 4.66 | 12.00 | 3.47 | 0.213 |
| | 9-2-75 | 4.92 | 12.66 | 3.67 | 0.227 | 4.25 | 10.94 | 3.02 | 0.194 |
| Average | | 4.81 | 12.38 | 3.58 | 0.221 | 4.43 | 11.41 | 3.25 | 0.203 |

## TABLE H-3. PARTICULATE EMISSION RATES - MERCEDES 300D

47mm Size Filters

| | | Fiberglass | | | | Fluoropore | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test | Date | g/test | g/hr | g/kg fuel | g/km | g/test | g/hr | g/kg fuel | g/km |
| FTP | 10-7-75 | 3.43 | 8.54 | 3.08 | 0.272 | 2.95 | 7.69 | 2.77 | 0.244 |
| Cold | 10-8-75 | 3.99 | 10.35 | 3.73 | 0.330 | 3.32 | 8.80 | 3.12 | 0.296 |
| | 10-9-75 | 3.84 | 10.00 | 3.60 | 0.319 | 3.20 | 8.33 | 3.00 | 0.266 |
| Average | | 3.75 | 9.63 | 3.47 | 0.307 | 3.16 | 8.27 | 2.96 | 0.269 |
| FTP | 10-7-75 | 3.59 | 9.35 | 4.14 | 0.298 | 3.33 | 8.66 | 3.83 | 0.275 |
| Hot | 10-8-75 | 3.75 | 9.76 | 4.32 | 0.310 | 3.26 | 8.49 | 3.76 | 0.270 |
| | 10-9-75 | 3.76 | 9.79 | 4.34 | 0.311 | 3.35 | 8.71 | 3.86 | 0.277 |
| Average | | 3.70 | 9.63 | 4.27 | 0.306 | 3.31 | 8.62 | 3.82 | 0.274 |
| 1975 | 10-7-75 | 3.52 | 9.00 | 3.68 | 0.286 | 3.17 | 8.24 | 3.37 | 0.262 |
| FTP | 10-8-75 | 3.85 | 10.01 | 4.07 | 0.319 | 3.29 | 8.62 | 3.48 | 0.281 |
| | 10-9-75 | 3.79 | 9.88 | 4.02 | 0.314 | 3.29 | 8.55 | 3.49 | 0.272 |
| Average | | 3.72 | 9.63 | 3.92 | 0.306 | 3.25 | 8.47 | 3.44 | 0.272 |
| FET | 10-7-75 | 3.99 | 18.76 | 3.63 | 0.242 | 3.64 | 17.14 | 3.32 | 0.221 |
| SET | 10-7-75 | 5.00 | 12.89 | 3.43 | 0.232 | 4.80 | 12.35 | 3.26 | 0.220 |

## TABLE H-4. PARTICULATE EMISSION RATES - PEUGEOT 204D
47mm Size Filters

| | | Fiberglass | | | | Fluoropore | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test | Date | g/test | g/hr | g/kg fuel | g/km | g/test | g/hr | g/kg fuel | g/km |
| FTP | 10-6-75 | 2.81 | 7.30 | 4.57 | 0.266 | 2.76 | 7.19 | 3.90 | 0.226 |
| Cold | 10-7-75 | 3.45 | 8.49 | 4.91 | 0.285 | 2.76 | 7.17 | 3.92 | 0.227 |
| | 10-8-75 | 2.89 | 7.51 | 4.10 | 0.239 | 2.44 | 6.36 | 3.45 | 0.201 |
| Average | | 3.05 | 7.77 | 4.53 | 0.263 | 2.65 | 6.91 | 3.76 | 0.218 |
| FTP | 10-6-75 | 2.42 | 6.31 | 3.64 | 0.200 | 2.21 | 5.75 | 3.32 | 0.182 |
| Hot | 10-7-75 | 3.14 | 8.18 | 4.27 | 0.233 | 2.98 | 6.46 | 3.72 | 0.204 |
| | 10-8-75 | 2.70 | 7.02 | 4.05 | 0.221 | 2.23 | 5.80 | 3.57 | 0.182 |
| Average | | 2.75 | 7.17 | 3.99 | 0.218 | 2.47 | 6.00 | 3.54 | 0.189 |
| 1975 | 10-6-75 | 2.58 | 6.74 | 4.04 | 0.228 | 2.45 | 6.37 | 3.57 | 0.218 |
| FTP | 10-7-75 | 3.27 | 8.31 | 4.54 | 0.255 | 2.88 | 6.77 | 3.81 | 0.214 |
| | 10-8-75 | 2.78 | 7.23 | 4.07 | 0.229 | 2.32 | 6.04 | 3.52 | 0.190 |
| Average | | 2.89 | 7.44 | 4.23 | 0.237 | 2.55 | 6.39 | 3.63 | 0.207 |
| FET | 10-6-75 | 3.06 | 14.41 | 4.10 | 0.185 | 3.00 | 14.15 | 4.02 | 0.182 |
| SET | 10-6-75 | 3.26 | 8.41 | 3.19 | 0.150 | 2.90 | 7.48 | 2.83 | 0.132 |

## TABLE H-5. PARTICULATE EMISSION RATES - PERKINS 6-247

47mm Size Filters

| | | Fiberglass | | | | Fluoropore | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test | Date | g/test | g/hr | g/kg fuel | g/km | g/test | g/hr | g/kg fuel | g/km |
| FTP | 12-3-75 | 6.31 | 16.43 | 7.50 | 0.522 | 5.58 | 14.54 | 6.27 | 0.462 |
| Cold | 12-4-75 | 6.10 | 15.87 | 6.26 | 0.505 | 5.56 | 14.49 | 5.70 | 0.460 |
| | 12-5-75 | 6.67 | 17.37 | 7.50 | 0.553 | 6.18 | 16.08 | 6.94 | 0.511 |
| Average | | 6.36 | 16.56 | 7.09 | 0.526 | 5.77 | 15.04 | 6.30 | 0.478 |
| FTP | 12-3-75 | 5.44 | 14.17 | 6.12 | 0.451 | 5.30 | 13.80 | 5.96 | 0.439 |
| Hot | 12-4-75 | 5.82 | 15.15 | 6.54 | 0.483 | 5.32 | 13.84 | 5.98 | 0.440 |
| | 12-5-57 | 6.13 | 15.95 | 6.46 | 0.508 | 5.65 | 14.70 | 5.95 | 0.468 |
| Average | | 5.80 | 15.09 | 6.37 | 0.481 | 5.42 | 14.11 | 5.96 | 0.449 |
| 1975 | 12-3-75 | 5.81 | 15.14 | 6.71 | 0.481 | 5.42 | 14.12 | 6.09 | 0.449 |
| FTP | 12-4-75 | 5.94 | 15.47 | 6.42 | 0.492 | 5.42 | 14.12 | 5.86 | 0.449 |
| | 12-5-75 | 6.36 | 16.56 | 6.91 | 0.527 | 5.88 | 15.29 | 6.38 | 0.486 |
| Average | | 6.04 | 15.72 | 6.68 | 0.500 | 5.57 | 14.51 | 6.11 | 0.461 |
| FET | 12-3-75 | 5.51 | 25.95 | 4.79 | 0.335 | 5.39 | 25.36 | 4.68 | 0.327 |
| SET | 12-3-75 | 6.67 | 17.18 | 4.33 | 0.307 | 6.49 | 16.71 | 4.21 | 0.299 |

# APPENDIX I

# SULFATE AND $SO_2$ EMISSION RATES FOR FIVE LD DIESEL VEHICLES

## TABLE I-1. SULFATE AND $SO_2$ EMISSION RESULTS
### Mercedes 220D Comprex

| | | Sulfate ($SO_4^=$) | | | | $SO_2$ | | |
|---|---|---|---|---|---|---|---|---|
| Test | Date | mg/hr | mg/km | mg/kg fuel | as % S in Fuel | Date | g/km | as % S in Fuel |
| FTP | 8-26-75 | 238.1 | 7.58 | 95.0 | 1.37 | 11-21-75 | - | - |
| Cold | 8-27-75 | 300.5 | 9.56 | 119.9 | 1.72 | 11-24-75 | 0.35 | 93.3 |
| | 8-28-75 | 261.5 | 8.32 | 104.3 | 1.50 | 11-25-75 | 0.38 | 111.2 |
| Average | | 266.7 | 8.49 | 106.4 | 1.53 | | 0.37 | 102.2 |
| FTP | 8-26-75 | 169.8 | 5.40 | 76.5 | 1.10 | 11-21-75 | 0.31 | 91.0 |
| Hot | 8-27-75 | 210.9 | 6.70 | 94.8 | 1.36 | 11-24-75 | - | - |
| | 8-28-75 | 177.6 | 5.65 | 80.0 | 1.15 | 11-25-75 | 0.33 | 103.4 |
| Average | | 186.1 | 5.92 | 83.8 | 1.20 | | 0.32 | 97.2 |
| 1975 | 8-26-75 | 199.2 | 6.33 | 84.4 | 1.22 | 11-21-75 | - | - |
| FTP | 8-27-75 | 249.4 | 7.93 | 105.6 | 1.51 | 11-24-75 | - | - |
| | 8-28-75 | 213.6 | 6.80 | 90.4 | 1.30 | 11-25-75 | 0.35 | 106.8 |
| Average | | 220.7 | 7.02 | 93.5 | 1.34 | | 0.35 | 106.8 |
| FET | 8-27-75 | 557.6 | 7.19 | 121.9 | 1.75 | 11-24-75 | 0.26 | 97.3 |
| | 8-28-75 | 538.9 | 6.95 | 117.7 | 1.69 | 11-25-75 | 0.28 | 106.0 |
| Average | | 548.3 | 7.07 | 119.8 | 1.72 | | 0.27 | 101.6 |
| SET | 8-27-75 | 320.6 | 5.73 | 91.2 | 1.31 | 11-24-75 | 0.25 | 85.4 |
| | 8-28-75 | 319.4 | 5.70 | 90.8 | 1.30 | 11-25-75 | 0.25 | 92.6 |
| Average | | 320.0 | 5.72 | 91.0 | 1.31 | | 0.25 | 89.0 |

## TABLE I-2. SULFATE AND $SO_2$ EMISSION RESULTS

### Mercedes 240D

| | | Sulfate ($SO4^{=}$) | | | | $SO_2$ | | |
|---|---|---|---|---|---|---|---|---|
| Test | Date | mg/hr | mg/km | mg/kg fuel | as % S in Fuel | Date | g/km | as % S in Fuel |
| FTP | 8-22-75 | 258.0 | 8.21 | 103.2 | 1.48 | 11-12-75 | 0.30 | 80.1 |
| Cold | 8-29-75 | 340.5 | 10.84 | 136.2 | 1.96 | 11-13-75 | 0.43 | 121.3 |
| | 9-2-75 | 220.5 | 7.01 | 88.2 | 1.27 | 11-14-75 | 0.30 | 81.5 |
| Average | | 273.0 | 8.69 | 109.2 | 1.57 | | 0.34 | 94.3 |
| FTP | 8-22-75 | 234.3 | 7.54 | 104.5 | 1.50 | 11-12-75 | 0.30 | 86.8 |
| Hot | 8-29-75 | 267.7 | 8.52 | 118.1 | 1.70 | 11-13-75 | 0.31 | 94.3 |
| | 9-2-75 | 189.4 | 6.03 | 83.6 | 1.20 | 11-14-75 | 0.31 | 94.6 |
| Average | | 230.4 | 7.36 | 102.0 | 1.47 | | 0.31 | 91.9 |
| 1975 | 8-22-75 | 244.5 | 7.82 | 103.9 | 1.49 | 11-12-75 | 0.30 | 80.4 |
| FTP | 8-29-75 | 290.0 | 9.51 | 125.9 | 1.81 | 11-13-75 | 0.36 | 105.8 |
| | 9-2-75 | 206.4 | 6.44 | 85.6 | 1.23 | 11-14-75 | 0.30 | 89.0 |
| Average | | 246.9 | 7.92 | 105.1 | 1.51 | | 0.32 | 91.7 |
| FET | 8-22-75 | 957.7 | 12.41 | 212.4 | 3.04 | 11-12-75 | 0.26 | 91.4 |
| | 8-29-75 | 736.4 | 9.49 | 162.7 | 2.34 | 11-13-75 | 0.26 | 101.6 |
| | 9-2-75 | 676.1 | 8.72 | 149.4 | 2.14 | 11-14-75 | 0.30 | 111.9 |
| Average | | 790.0 | 10.20 | 174.8 | 2.51 | | 0.27 | 101.6 |
| SET | 8-22-75 | 594.5 | 10.62 | 172.6 | 2.48 | 11-12-75 | 0.24 | 83.4 |
| | 8-29-75 | 514.6 | 9.19 | 149.6 | 2.15 | 11-13-75 | 0.25 | 91.0 |
| | 9-2-75 | 364.3 | 6.51 | 105.9 | 1.52 | 11-14-75 | 0.25 | 86.6 |
| Average | | 491.1 | 8.77 | 142.7 | 2.05 | | 0.25 | 87.0 |

## TABLE I-3. SULFATE AND $SO_2$ EMISSION RESULTS

Mercedes 300D

| | | Sulfate ($SO_4^=$) | | | | $SO_2$ | | |
|---|---|---|---|---|---|---|---|---|
| Test | Date | mg/hr | mg/km | mg/kg fuel | as % S in Fuel | Date | g/km | as % S in Fuel |
| FTP | 10-7-75 | 376.2 | 11.97 | 135.6 | 1.94 | 11-12-75 | 0.33 | 84.9 |
| Cold | 10-8-75 | 313.6 | 9.98 | 113.0 | 1.62 | 11-13-75 | 0.35 | 87.7 |
| | 10-9-75 | 261.3 | 8.31 | 94.1 | 1.35 | 11-14-75 | 0.33 | 85.7 |
| Average | | 317.0 | 10.09 | 114.2 | 1.64 | | 0.34 | 86.1 |
| FTP | 10-7-75 | 249.3 | 7.93 | 110.6 | 1.59 | 11-12-75 | 0.27 | 84.7 |
| Hot | 10-8-75 | 288.5 | 9.18 | 128.1 | 1.84 | 11-13-75 | 0.30 | 86.9 |
| | 10-9-75 | 257.6 | 8.20 | 114.3 | 1.64 | 11-14-75 | 0.28 | 86.9 |
| Average | | 265.1 | 8.44 | 117.7 | 1.69 | | 0.28 | 86.2 |
| 1975 | 10-7-75 | 303.9 | 9.67 | 121.4 | 1.74 | 11-12-75 | 0.30 | 84.8 |
| FTP | 10-8-75 | 299.3 | 9.52 | 121.6 | 1.74 | 11-13-75 | 0.32 | 87.2 |
| | 10-9-75 | 259.2 | 8.25 | 105.6 | 1.52 | 11-14-75 | 0.30 | 86.4 |
| Average | | 287.5 | 9.15 | 116.2 | 1.67 | | 0.31 | 86.1 |
| FET | 10-7-75 | 817.7 | 10.54 | 160.3 | 2.30 | 11-12-75 | - | - |
| | 10-7-75 | 928.8 | 11.90 | 180.9 | 2.31 | 11-13-75 | 0.30 | 94.4 |
| | | | | | | 11-14-75 | 0.33 | 110.4 |
| Average | | 873.3 | 11.22 | 170.6 | 2.31 | | 0.32 | 102.4 |
| SET | 10-7-75 | 629.9 | 11.25 | 166.8 | 2.39 | 11-12-75 | - | - |
| | 10-7-75 | 519.8 | 9.30 | 137.6 | 1.98 | 11-13-75 | 0.25 | 80.0 |
| | | | | | | 11-14-75 | 0.27 | 88.8 |
| Average | | 574.9 | 10.27 | 152.2 | 2.19 | | 0.26 | 84.4 |

## TABLE I-4. SULFATE AND $SO_2$ EMISSION RESULTS

Peugeot 204D

| | | Sulfate ($SO_4^=$) | | | | $SO_2$ | | |
|---|---|---|---|---|---|---|---|---|
| Test | Date | mg/hr | mg/km | mg/kg fuel | as % S in Fuel | Date | g/km | as % S in Fuel |
| FTP | 10-6-75 | 204.4 | 6.51 | 111.4 | 1.61 | 11-21-75 | 0.26 | 88.9 |
| Cold | 10-7-75 | 237.2 | 7.55 | 129.9 | 1.87 | 11-24-75 | 0.24 | 94.0 |
| | 10-8-75 | 195.3 | 6.22 | 106.9 | 1.54 | 11-25-75 | 0.25 | 91.1 |
| Average | | 212.3 | 6.76 | 116.0 | 1.67 | | 0.25 | 91.3 |
| FTP | 10-6-75 | 172.8 | 5.49 | 100.1 | 1.43 | 11-21-75 | 0.29 | 111.0 |
| Hot | 10-7-75 | 251.6 | 8.00 | 145.8 | 2.09 | 11-24-75 | 0.28 | 111.5 |
| | 10-8-75 | 202.3 | 6.43 | 117.2 | 1.68 | 11-25-75 | 0.25 | 95.0 |
| Average | | 208.9 | 6.64 | 121.0 | 1.73 | | 0.27 | 105.8 |
| 1975 | 10-6-75 | 186.4 | 5.92 | 105.0 | 1.51 | 11-21-75 | 0.28 | 101.5 |
| FTP | 10-7-75 | 245.4 | 7.81 | 139.0 | 2.00 | 11-24-75 | 0.26 | 104.0 |
| | 10-8-75 | 199.3 | 6.34 | 113.2 | 1.62 | 11-25-75 | 0.25 | 93.3 |
| Average | | 210.3 | 6.69 | 119.0 | 1.71 | | 0.26 | 99.6 |
| FET | 10-6-75 | 606.9 | 7.82 | 173.6 | 2.49 | 11-21-75 | 0.26 | 117.9 |
| | 10-6-75 | 473.5 | 6.10 | 135.4 | 1.94 | 11-24-75 | 0.17 | 88.6 |
| | | | | | | 11-25-75 | 0.20 | 93.2 |
| Average | | 540.2 | 6.96 | 154.5 | 2.22 | | 0.21 | 99.9 |
| SET | 10-6-75 | 278.7 | 4.97 | 105.7 | 1.55 | 11-21-75 | - | - |
| | 10-6-75 | 293.8 | 5.24 | 111.4 | 1.64 | 11-24-75 | 0.20 | 95.1 |
| | | | | | | 11-25-75 | - | - |
| Average | | 286.2 | 5.10 | 108.5 | 1.60 | | 0.20 | 95.1 |

# TABLE I-5. SULFATE AND $SO_2$ EMISSION RESULTS

## Perkins 6-247

| | | Sulfate ($SO_4^=$) | | | | $SO_2$ | | |
|---|---|---|---|---|---|---|---|---|
| Test | Date | mg/hr | mg/km | mg/kg fuel | as % S in Fuel | Date | g/km | as % S in Fuel |
| FTP | 12-3-75 | 343.8 | 10.89 | 135.9 | 1.95 | 11-21-75 | 0.43 | 113.7 |
| Cold | 12-4-75 | 334.4 | 10.61 | 132.2 | 1.90 | 11-24-75 | 0.28 | - |
| | 12-5-75 | 358.0 | 11.39 | 141.6 | 2.03 | 11-25-75 | 0.38 | 102.4 |
| Average | | 345.4 | 10.96 | 136.6 | 1.96 | | 0.36 | 108.1 |
| FTP | 12-3-75 | 332.0 | 10.56 | 143.7 | 2.06 | 11-21-75 | 0.39 | 103.9 |
| Hot | 12-4-75 | 317.0 | 10.12 | 138.4 | 1.97 | 11-24-75 | 0.36 | 103.2 |
| | 12-5-75 | 352.0 | 11.20 | 152.3 | 2.05 | 11-25-75 | 0.35 | 112.4 |
| Average | | 333.7 | 10.62 | 144.8 | 2.03 | | 0.37 | 106.5 |
| 1975 | 12-3-75 | 337.0 | 10.70 | 140.3 | 2.01 | 11-21-75 | 0.41 | 108.1 |
| FTP | 12-4-75 | 324.5 | 10.33 | 135.7 | 1.94 | 11-24-75 | 0.32 | - |
| | 12-5-75 | 354.6 | 11.28 | 147.7 | 2.04 | 11-25-75 | 0.36 | 108.1 |
| Average | | 338.7 | 10.77 | 141.2 | 2.00 | | 0.36 | 108.1 |
| FET | 12-3-75 | 1021.1 | 13.17 | 188.9 | 2.71 | 11-21-75 | 0.33 | 97.9 |
| | 12-3-75 | 981.2 | 12.65 | 181.5 | 2.60 | 11-24-75 | 0.32 | 99.0 |
| | | | | | | 11-25-75 | 0.28 | 92.8 |
| Average | | 1001.1 | 12.91 | 185.2 | 2.66 | | 0.31 | 96.6 |
| SET | 12-3-75 | 637.8 | 11.54 | 163.2 | 2.31 | 11-21-75 | 0.27 | 81.5 |
| | 12-3-75 | 616.6 | 11.15 | 157.8 | 2.24 | 11-24-75 | 0.26 | 81.6 |
| | | | | | | 11-25-75 | 0.28 | 88.0 |
| Average | | 627.2 | 11.34 | 160.5 | 2.28 | | 0.27 | 83.7 |

# APPENDIX J

# ODOR RATINGS BY TRAINED PANEL FOR FIVE LD DIESEL VEHICLES

## TABLE J-1. ODOR SUMMARY - MERCEDES 220D COMPREX EVALUATION 100:1 DILUTION

| Operating Condition | Load | Date | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|---|
| 1680 rpm | 2% | 4/7/76 | 2.4 | 1.0 | 0.9 | 0.6 | 0.4 |
| | | 4/9/76 | 2.8 | 1.0 | 0.9 | 0.6 | 0.6 |
| | | Average | 2.6 | 1.0 | 0.9 | 0.6 | 0.5 |
| 1680 rpm | 50% | 4/7/76 | 2.5 | 1.0 | 1.0 | 0.4 | 0.4 |
| 32 mph | | 4/9/76 | 2.2 | 1.0 | 0.9 | 0.6 | 0.4 |
| | | Average | 2.4 | 1.0 | 1.0 | 0.5 | 0.4 |
| 1680 rpm | 100% | 4/7/76 | 2.7 | 1.0 | 1.0 | 0.7 | 0.5 |
| 32 mph | | 4/9/76 | 3.1 | 1.0 | 1.0 | 0.8 | 0.6 |
| | | Average | 2.9 | 1.0 | 1.0 | 0.8 | 0.6 |
| 2800 rpm | 2% | 4/7/76 | 3.4 | 1.0 | 1.0 | 0.8 | 0.6 |
| | | 4/9/76 | 3.5 | 1.1 | 1.0 | 0.9 | 0.6 |
| | | Average | 3.5 | 1.1 | 1.0 | 0.9 | 0.6 |
| 2800 rpm | 50% | 4/7/76 | 2.9 | 1.0 | 0.9 | 0.7 | 0.7 |
| 56 mph | | 4/9/76 | 2.9 | 1.0 | 0.9 | 0.8 | 0.6 |
| | | Average | 2.9 | 1.0 | 0.9 | 0.8 | 0.7 |
| 2800 rpm | 100% | 4/7/76 | 2.9 | 1.0 | 1.0 | 0.6 | 0.7 |
| 56 mph | | 4/9/76 | 2.9 | 1.0 | 1.0 | 0.7 | 0.5 |
| | | Average | 2.9 | 1.0 | 1.0 | 0.7 | 0.6 |
| Idle | | 4/7/76 | 3.1 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 4/9/76 | 3.0 | 1.0 | 0.9 | 0.9 | 0.6 |
| | | Average | 3.1 | 1.0 | 1.0 | 0.8 | 0.6 |
| Idle-Acceleration | | 4/7/76 | 3.6 | 1.1 | 1.0 | 0.8 | 0.8 |
| | | 4/9/76 | 3.8 | 1.2 | 1.0 | 0.9 | 0.9 |
| | | Average | 3.7 | 1.1 | 1.0 | 0.9 | 0.9 |
| Acceleration | | 4/7/76 | 3.0 | 1.0 | 1.0 | 0.8 | 0.5 |
| | | 4/9/76 | 3.2 | 1.0 | 1.0 | 0.8 | 0.8 |
| | | Average | 3.1 | 1.0 | 1.0 | 0.8 | 0.7 |
| Deceleration | | 4/7/76 | 3.1 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 4/9/76 | 2.9 | 1.0 | 1.0 | 0.7 | 0.5 |
| | | Average | 3.0 | 1.0 | 1.0 | 0.7 | 0.6 |
| Cold Start | | 4/7/76 | 3.1 | 1.0 | 1.0 | 0.7 | 0.7 |
| | | 4/9/76 | 3.0 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | Average | 3.1 | 1.0 | 1.0 | 0.7 | 0.7 |

## TABLE J-2. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Mercedes 220D Comprex Dilution Ratio: 100:1
Date: April 7, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 1. | Inter-2 | 2.6 | 1.0 | 1.0 | 0.6 | 0.6 |
| 8. | | 2.3 | 1.0 | 0.9 | 0.4 | 0.3 |
| 14. | | 2.4 | 1.0 | 0.8 | 0.8 | 0.2 |
| | | 2.4 | 1.0 | 0.9 | 0.6 | 0.4 |
| 6. | Inter-50 | 3.2 | 1.0 | 1.0 | 0.6 | 0.8 |
| 13. | | 1.9 | 1.0 | 1.0 | 0.3 | 0.2 |
| 19. | | 2.3 | 1.0 | 1.0 | 0.3 | 0.3 |
| | | 2.5 | 1.0 | 1.0 | 0.4 | 0.4 |
| 5. | Inter-100 | 2.7 | 1.0 | 1.0 | 0.6 | 0.4 |
| 12. | | 3.1 | 1.0 | 1.0 | 0.8 | 0.7 |
| 20. | | 2.4 | 1.0 | 1.0 | 0.6 | 0.3 |
| | | 2.7 | 1.0 | 1.0 | 0.7 | 0.5 |
| 4. | High-2 | 3.2 | 1.0 | 1.0 | 0.7 | 0.4 |
| 10. | | 3.2 | 1.0 | 1.0 | 0.8 | 0.6 |
| 16. | | 3.7 | 1.0 | 1.0 | 0.8 | 0.9 |
| | | 3.4 | 1.0 | 1.0 | 0.8 | 0.6 |
| 7. | High-50 | 2.8 | 1.0 | 0.8 | 0.6 | 0.6 |
| 15. | | 3.2 | 1.0 | 1.0 | 0.7 | 0.9 |
| 21. | | 2.8 | 1.0 | 0.9 | 0.7 | 0.6 |
| | | 2.9 | 1.0 | 0.9 | 0.7 | 0.7 |
| 2. | High-100 | 2.9 | 1.0 | 1.0 | 0.7 | 0.7 |
| 9. | | 3.2 | 1.0 | 1.0 | 0.7 | 0.7 |
| 17. | | 2.7 | 1.0 | 1.0 | 0.4 | 0.6 |
| | | 2.9 | 1.0 | 1.0 | 0.6 | 0.7 |
| 3. | Idle | 3.4 | 1.1 | 1.0 | 0.6 | 0.9 |
| 11. | | 2.9 | 1.0 | 0.9 | 0.8 | 0.6 |
| 18. | | 3.0 | 1.0 | 1.0 | 0.8 | 0.4 |
| | | 3.1 | 1.0 | 1.0 | 0.7 | 0.6 |
| 22. | Idle-Acceleration | 3.8 | 1.0 | 1.0 | 1.0 | 0.7 |
| 26. | | 4.2 | 1.2 | 1.0 | 0.9 | 1.1 |
| 28. | | 3.4 | 1.0 | 1.0 | 0.8 | 0.7 |
| 32. | | 3.1 | 1.1 | 1.0 | 0.6 | 0.7 |
| | | 3.6 | 1.1 | 1.0 | 0.8 | 0.8 |
| 23. | Acceleration | 2.7 | 1.0 | 1.0 | 0.6 | 0.3 |
| 25. | | 3.2 | 1.0 | 1.0 | 1.0 | 0.5 |
| 29. | | 2.9 | 1.0 | 1.0 | 0.7 | 0.6 |
| 33. | | 3.1 | 1.0 | 1.0 | 0.8 | 0.7 |
| | | 3.0 | 1.0 | 1.0 | 0.8 | 0.5 |
| 24. | Deceleration | 2.8 | 1.0 | 1.0 | 0.7 | 0.4 |
| 27. | | 3.4 | 1.0 | 1.0 | 0.8 | 0.8 |
| 30. | | 2.9 | 1.0 | 1.0 | 0.5 | 0.6 |
| 31. | | 3.3 | 1.0 | 1.0 | 0.8 | 0.7 |
| | | 3.1 | 1.0 | 1.0 | 0.7 | 0.6 |
| | Cold Start | 3.1 | 1.0 | 1.0 | 0.7 | 0.7 |

## TABLE J-3. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Mercedes 220D Comprex Dilution Ratio: 100:1
Date: April 9, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 8. | Inter-2 | 3.9 | 1.1 | 0.9 | 0.9 | 1.0 |
| 14. | | 2.4 | 1.0 | 0.9 | 0.6 | 0.4 |
| 21. | | 2.1 | 1.0 | 1.0 | 0.4 | 0.4 |
| | | 2.8 | 1.0 | 0.9 | 0.6 | 0.6 |
| 3. | Inter-50 | 2.4 | 1.0 | 0.9 | 0.8 | 0.6 |
| 9. | | 2.1 | 1.0 | 0.9 | 0.6 | 0.3 |
| 16. | | 2.0 | 1.0 | 0.9 | 0.5 | 0.3 |
| | | 2.2 | 1.0 | 0.9 | 0.6 | 0.4 |
| 2. | Inter-100 | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| 10. | | 3.0 | 1.0 | 1.0 | 0.9 | 0.5 |
| 17 | | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |
| | | 3.1 | 1.0 | 1.0 | 0.8 | 0.6 |
| 6. | High-2 | 2.9 | 1.0 | 1.0 | 0.9 | 0.3 |
| 12. | | 4.3 | 1.3 | 1.0 | 1.0 | 0.8 |
| 18. | | 3.4 | 1.0 | 0.9 | 0.8 | 0.8 |
| | | 3.5 | 1.1 | 1.0 | 0.9 | 0.6 |
| 1. | High-50 | 2.7 | 1.0 | 0.9 | 0.7 | 0.6 |
| 7. | | 3.3 | 1.0 | 0.9 | 0.9 | 0.8 |
| 15. | | 2.6 | 1.0 | 0.9 | 0.8 | 0.4 |
| | | 2.9 | 1.0 | 0.9 | 0.8 | 0.6 |
| 5. | High-100 | 2.4 | 1.0 | 1.0 | 0.6 | 0.4 |
| 13. | | 3.5 | 1.1 | 1.0 | 0.8 | 0.6 |
| 20. | | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |
| | | 2.9 | 1.0 | 1.0 | 0.7 | 0.5 |
| 4. | Idle | 3.0 | 1.0 | 0.9 | 0.8 | 0.6 |
| 11. | | 2.6 | 1.0 | 0.8 | 1.0 | 0.4 |
| 19. | | 3.3 | 1.0 | 0.9 | 0.8 | 0.9 |
| | | 3.0 | 1.0 | 0.9 | 0.9 | 0.6 |
| 23. | Idle - Acceleration | 3.8 | 1.0 | 1.0 | 1.0 | 0.8 |
| 27. | | 4.3 | 1.3 | 1.0 | 0.8 | 1.1 |
| 29. | | 3.6 | 1.3 | 1.0 | 0.9 | 0.8 |
| 33 | | 3.4 | 1.0 | 1.0 | 0.9 | 0.8 |
| | | 3.8 | 1.2 | 1.0 | 0.9 | 0.9 |
| 22. | Acceleration | 3.0 | 1.0 | 1.0 | 0.6 | 0.8 |
| 26. | | 3.6 | 1.0 | 1.0 | 1.0 | 0.8 |
| 30. | | 3.6 | 1.0 | 1.0 | 0.9 | 0.9 |
| 32. | | 2.4 | 1.0 | 1.0 | 0.5 | 0.5 |
| | | 3.2 | 1.0 | 1.0 | 0.8 | 0.8 |
| 24. | Deceleration | 2.6 | 1.0 | 1.0 | 0.4 | 0.6 |
| 25. | | 2.9 | 1.0 | 1.0 | 0.8 | 0.5 |
| 28. | | 3.3 | 1.0 | 1.0 | 1.0 | 0.5 |
| 31. | | 2.6 | 1.0 | 1.0 | 0.6 | 0.5 |
| | | 2.9 | 1.0 | 1.0 | 0.7 | 0.5 |
| | Cold Start | 3.0 | 1.0 | 1.0 | 0.7 | 0.6 |

### TABLE J-4 ODOR SUMMARY -- MERCEDES 240D EVALUATION
### 100:1 DILUTION

| Operating Condition | Load | Date | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|---|
| 1800 rpm | 2% | 4/20/76 | 2.1 | 1.0 | 0.9 | 0.6 | 0.3 |
| | | 4/22/76 | 2.2 | 1.0 | 1.0 | 0.4 | 0.4 |
| | | Average | 2.2 | 1.0 | 1.0 | 0.5 | 0.4 |
| 1800 rpm 33 mph | 50% | 4/20/76 | 2.0 | 1.0 | 0.8 | 0.5 | 0.3 |
| | | 4/22/76 | 2.2 | 1.0 | 0.9 | 0.6 | 0.5 |
| | | Average | 2.1 | 1.0 | 0.9 | 0.6 | 0.4 |
| 1800 rpm 33 mph | 100% | 4/20/76 | 2.3 | 1.0 | 0.7 | 0.5 | 0.5 |
| | | 4/22/76 | 2.4 | 1.0 | 1.0 | 0.5 | 0.6 |
| | | Average | 2.4 | 1.0 | 0.9 | 0.5 | 0.6 |
| 3000 rpm | 2% | 4/20/76 | 2.2 | 1.0 | 0.9 | 0.6 | 0.2 |
| | | 4/22/76 | 2.8 | 1.0 | 1.0 | 0.6 | 0.7 |
| | | Average | 2.5 | 1.0 | 1.0 | 0.6 | 0.5 |
| 3000 rpm 56 mph | 50% | 4/20/76 | 2.6 | 1.0 | 0.9 | 0.7 | 0.7 |
| | | 4/22/76 | 2.4 | 1.0 | 1.0 | 0.5 | 0.5 |
| | | Average | 2.5 | 1.0 | 1.0 | 0.6 | 0.6 |
| 3000 rpm 56 mph | 100% | 4/20/76 | 2.7 | 1.0 | 0.9 | 0.7 | 0.7 |
| | | 4/22/76 | 2.6 | 1.0 | 1.0 | 0.6 | 0.6 |
| | | Average | 2.7 | 1.0 | 1.0 | 0.7 | 0.7 |
| Idle | | 4/20/76 | 2.2 | 1.0 | 0.8 | 0.5 | 0.3 |
| | | 4/22/76 | 2.0 | 1.0 | 1.0 | 0.4 | 0.4 |
| | | Average | 2.1 | 1.0 | 0.9 | 0.5 | 0.4 |
| Idle-Acceleration | | 4/20/76 | 2.5 | 1.0 | 0.9 | 0.7 | 0.7 |
| | | 4/22/76 | 2.6 | 1.0 | 1.0 | 0.4 | 0.6 |
| | | Average | 2.6 | 1.0 | 1.0 | 0.6 | 0.7 |
| Acceleration | | 4/20/76 | 2.6 | 1.0 | 1.0 | 0.5 | 0.6 |
| | | 4/22/76 | 2.3 | 1.0 | 1.0 | 0.4 | 0.6 |
| | | Average | 2.5 | 1.0 | 1.0 | 0.5 | 0.6 |
| Deceleration | | 4/20/76 | 2.7 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 4/22/76 | 2.2 | 1.0 | 1.0 | 0.4 | 0.5 |
| | | Average | 2.5 | 1.0 | 1.0 | 0.6 | 0.6 |
| Cold Start | | 4/20/76 | 3.0 | 1.0 | 0.9 | 0.8 | 0.6 |
| | | 4/22/76 | 3.3 | 1.0 | 1.0 | 0.9 | 0.9 |
| | | Average | 3.2 | 1.0 | 1.0 | 0.9 | 0.8 |

## TABLE J-5. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Mercedes 240D Dilution Ratio: 100:1
Date: April 20, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 7. | Inter-0 | 2.3 | 1.0 | 1.0 | 0.6 | 0.2 |
| 11. | | 1.9 | 1.0 | 0.8 | 0.6 | 0.2 |
| 16. | | 2.0 | 1.0 | 0.8 | 0.7 | 0.4 |
| | | 2.1 | 1.0 | 0.9 | 0.6 | 0.3 |
| 4. | Inter-50 | 1.8 | 1.0 | 0.7 | 0.4 | 0.2 |
| 14. | | 1.9 | 1.0 | 0.7 | 0.6 | 0.4 |
| 20. | | 2.2 | 1.0 | 0.9 | 0.4 | 0.4 |
| | | 2.0 | 1.0 | 0.8 | 0.5 | 0.3 |
| 3. | Inter-100 | 2.2 | 1.0 | 0.7 | 0.4 | 0.4 |
| 13. | | 2.9 | 1.0 | 0.9 | 0.8 | 0.6 |
| 21. | | 1.7 | 1.0 | 0.6 | 0.3 | 0.4 |
| | | 2.3 | 1.0 | 0.7 | 0.5 | 0.5 |
| 5. | High-0 | 1.8 | 1.0 | 0.8 | 0.4 | 0.2 |
| 10. | | 2.6 | 1.0 | 0.9 | 0.9 | 0.1 |
| 17. | | 2.1 | 1.0 | 0.9 | 0.4 | 0.3 |
| | | 2.2 | 1.0 | 0.9 | 0.6 | 0.2 |
| 2. | High-50 | 2.8 | 1.0 | 1.0 | 0.7 | 0.7 |
| 8. | | 3.1 | 1.0 | 1.0 | 0.8 | 0.9 |
| 15. | | 1.9 | 1.0 | 0.8 | 0.6 | 0.6 |
| | | 2.6 | 1.0 | 0.9 | 0.7 | 0.7 |
| 1. | High-100 | 2.3 | 1.0 | 1.0 | 0.4 | 0.3 |
| 9. | | 2.9 | 1.0 | 1.0 | 0.9 | 0.6 |
| 19. | | 2.9 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 2.7 | 1.0 | 1.0 | 0.7 | 0.5 |
| 6. | Idle | 2.3 | 1.0 | 0.8 | 0.5 | 0.4 |
| 12. | | 2.7 | 1.0 | 0.8 | 0.7 | 0.3 |
| 18. | | 1.7 | 1.0 | 0.7 | 0.3 | 0.3 |
| | | 2.2 | 1.0 | 0.8 | 0.5 | 0.3 |
| 23. | Idle-Acceleration | 2.7 | 1.0 | 0.8 | 0.7 | 0.8 |
| 28. | | 2.0 | 1.0 | 0.8 | 0.7 | 0.4 |
| 29. | | 2.4 | 1.0 | 0.9 | 0.6 | 0.6 |
| 31. | | 3.0 | 1.0 | 1.0 | 0.7 | 0.8 |
| | | 2.5 | 1.0 | 0.9 | 0.7 | 0.7 |
| 24. | Acceleration | 2.4 | 1.0 | 1.0 | 0.4 | 0.5 |
| 26. | | 2.6 | 1.0 | 1.0 | 0.6 | 0.6 |
| 30. | | 2.4 | 1.0 | 1.0 | 0.4 | 0.6 |
| 33. | | 3.1 | 1.0 | 1.0 | 0.4 | 0.8 |
| | | 2.6 | 1.0 | 1.0 | 0.5 | 0.6 |
| 22. | Deceleration | 2.6 | 1.0 | 0.9 | 0.6 | 0.4 |
| 25. | | 2.8 | 1.0 | 1.0 | 0.7 | 0.6 |
| 27. | | 2.7 | 1.0 | 0.9 | 0.8 | 0.6 |
| 32. | | 2.8 | 1.0 | 1.0 | 0.6 | 0.8 |
| | | 2.7 | 1.0 | 1.0 | 0.7 | 0.6 |
| | Cold Start | 3.0 | 1.0 | 0.9 | 0.8 | 0.6 |

## TABLE J-6. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Mercedes 240D
Dilution Ratio: 100:1
Date: April 22, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 6. | Inter-2 | 2.1 | 1.0 | 0.9 | 0.4 | 0.3 |
| 11. | | 2.3 | 1.0 | 1.0 | 0.4 | 0.4 |
| 15. | | 2.3 | 1.0 | 1.0 | 0.4 | 0.6 |
| | | 2.2 | 1.0 | 1.0 | 0.4 | 0.4 |
| 2. | Inter-50 | 2.0 | 1.0 | 0.9 | 0.6 | 0.4 |
| 8. | | 2.1 | 1.0 | 0.7 | 0.4 | 0.6 |
| 18. | | 2.4 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 2.2 | 1.0 | 0.9 | 0.6 | 0.5 |
| 1. | Inter-100 | 2.0 | 1.0 | 1.0 | 0.3 | 0.6 |
| 9. | | 2.4 | 1.0 | 0.9 | 0.6 | 0.4 |
| 19. | | 2.9 | 1.0 | 1.0 | 0.6 | 0.7 |
| | | 2.4 | 1.0 | 1.0 | 0.5 | 0.6 |
| 5. | High-2 | 2.7 | 1.0 | 1.0 | 0.6 | 0.7 |
| 12. | | 2.9 | 1.0 | 0.9 | 0.6 | 0.6 |
| 17. | | 2.7 | 1.0 | 1.0 | 0.6 | 0.7 |
| | | 2.8 | 1.0 | 1.0 | 0.6 | 0.7 |
| 7. | High-50 | 2.9 | 1.0 | 1.0 | 0.7 | 0.6 |
| 14. | | 2.3 | 1.0 | 1.0 | 0.3 | 0.6 |
| 20. | | 2.1 | 1.0 | 0.9 | 0.4 | 0.4 |
| | | 2.4 | 1.0 | 1.0 | 0.5 | 0.5 |
| 3. | High-100 | 2.7 | 1.0 | 1.0 | 0.6 | 0.6 |
| 13. | | 2.6 | 1.0 | 0.9 | 0.7 | 0.7 |
| 21. | | 2.6 | 1.0 | 1.0 | 0.4 | 0.4 |
| | | 2.6 | 1.0 | 1.0 | 0.6 | 0.6 |
| 4. | Idle | 1.9 | 1.0 | 1.0 | 0.4 | 0.6 |
| 10. | | 1.7 | 1.0 | 1.0 | 0.3 | 0.4 |
| 16. | | 2.3 | 1.0 | 1.0 | 0.4 | 0.3 |
| | | 2.0 | 1.0 | 1.0 | 0.4 | 0.4 |
| 24. | Idle-Acceleration | 2.9 | 1.0 | 1.0 | 0.3 | 0.7 |
| 26. | | 2.6 | 1.0 | 1.0 | 0.4 | 0.6 |
| 27. | | 2.4 | 1.0 | 1.0 | 0.4 | 0.6 |
| 32. | | 2.6 | 1.0 | 0.9 | 0.6 | 0.6 |
| | | 2.6 | 1.0 | 1.0 | 0.4 | 0.6 |
| 22. | Acceleration | 2.4 | 1.0 | 1.0 | 0.6 | 0.6 |
| 25. | | 2.3 | 1.0 | 1.0 | 0.3 | 0.6 |
| 29. | | 2.4 | 1.0 | 1.0 | 0.4 | 0.6 |
| 31. | | 2.1 | 1.0 | 0.9 | 0.3 | 0.6 |
| | | 2.3 | 1.0 | 1.0 | 0.4 | 0.6 |
| 23. | Deceleration | 1.9 | 0.9 | 0.9 | 0.6 | 0.1 |
| 28. | | 2.3 | 1.0 | 1.0 | 0.3 | 0.6 |
| 30. | | 2.4 | 1.0 | 1.0 | 0.4 | 0.7 |
| 33. | | 2.3 | 1.0 | 1.0 | 0.4 | 0.7 |
| | | 2.2 | 1.0 | 1.0 | 0.4 | 0.5 |
| | Cold Start | 3.3 | 1.0 | 1.0 | 0.9 | 0.9 |

## TABLE J-7. ODOR SUMMARY -- MERCEDES 300D EVALUATION
## 100:1 DILUTION

| Operating Condition | Load | Date | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|---|
| 1740 rpm | 2% | 4/14/76 | 2.3 | 1.0 | 0.9 | 0.4 | 0.4 |
| | | 4/16/76 | 2.3 | 1.0 | 0.8 | 0.8 | 0.5 |
| | | Average | 2.3 | 1.0 | 0.9 | 0.6 | 0.5 |
| 1740 rpm | 50% | 4/14/76 | 2.2 | 1.0 | 0.9 | 0.4 | 0.3 |
| 33 mph | | 4/16/76 | 2.1 | 1.0 | 0.9 | 0.5 | 0.3 |
| | | Average | 2.2 | 1.0 | 0.9 | 0.5 | 0.3 |
| 1740 rpm | 100% | 4/14/76 | 1.9 | 1.0 | 0.8 | 0.3 | 0.3 |
| 33 mph | | 4/16/76 | 2.1 | 1.0 | 0.9 | 0.5 | 0.3 |
| | | Average | 2.0 | 1.0 | 0.9 | 0.4 | 0.3 |
| 2900 rpm | 2% | 4/14/76 | 2.8 | 1.0 | 0.9 | 0.7 | 0.7 |
| | | 4/16/76 | 2.2 | 1.0 | 0.9 | 0.7 | 0.5 |
| | | Average | 2.5 | 1.0 | 0.9 | 0.7 | 0.6 |
| 2900 rpm | 50% | 4/14/76 | 3.2 | 1.0 | 1.0 | 0.8 | 0.7 |
| 56 mph | | 4/16/76 | 2.8 | 1.0 | 1.0 | 0.7 | 0.5 |
| | | Average | 3.0 | 1.0 | 1.0 | 0.8 | 0.6 |
| 2900 rpm | 100% | 4/14/76 | 3.0 | 1.0 | 1.0 | 0.7 | 0.6 |
| 56 mph | | 4/16/76 | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| | | Average | 2.8 | 1.0 | 1.0 | 0.7 | 0.5 |
| Idle | | 4/14/76 | 2.6 | 1.0 | 1.0 | 0.7 | 0.4 |
| | | 4/16/76 | 3.1 | 1.0 | 0.9 | 0.7 | 0.7 |
| | | Average | 2.9 | 1.0 | 1.0 | 0.7 | 0.6 |
| Idle - Acceleration | | 4/14/76 | 2.9 | 1.0 | 1.0 | 0.7 | 0.5 |
| | | 4/16/76 | 2.6 | 1.0 | 1.0 | 0.6 | 0.5 |
| | | Average | 2.8 | 1.0 | 1.0 | 0.7 | 0.5 |
| Acceleration | | 4/14/76 | 2.4 | 1.0 | 0.9 | 0.6 | 0.3 |
| | | 4/16/76 | 2.7 | 1.0 | 0.9 | 0.8 | 0.5 |
| | | Average | 2.6 | 1.0 | 0.9 | 0.7 | 0.4 |
| Deceleration | | 4/14/76 | 2.4 | 1.0 | 0.9 | 0.7 | 0.4 |
| | | 4/16/76 | 2.6 | 1.0 | 1.0 | 0.8 | 0.4 |
| | | Average | 2.5 | 1.0 | 1.0 | 0.8 | 0.4 |
| Cold Start | | 4/14/76 | 3.4 | 1.0 | 1.0 | 1.0 | 0.7 |
| | | 4/16/76 | 3.3 | 1.0 | 1.0 | 0.9 | 0.7 |
| | | Average | 3.4 | 1.0 | 1.0 | 1.0 | 0.7 |

## TABLE J-8. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Mercedes 300D    Dilution Ratio: 100:1
Date: April 14, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 6. | Inter-2 | 2.8 | 1.0 | 0.9 | 0.6 | 0.7 |
| 11. | | 1.6 | 1.0 | 0.8 | 0.2 | 0.1 |
| 15. | | 2.4 | 1.0 | 1.0 | 0.4 | 0.3 |
| | | 2.3 | 1.0 | 0.9 | 0.4 | 0.4 |
| 2. | Inter-50 | 2.4 | 1.0 | 0.9 | 0.6 | 0.4 |
| 8. | | 2.3 | 1.0 | 1.0 | 0.4 | 0.3 |
| 18. | | 2.0 | 1.0 | 0.9 | 0.3 | 0.3 |
| | | 2.2 | 1.0 | 0.9 | 0.4 | 0.3 |
| 1. | Inter-100 | 1.7 | 1.0 | 0.7 | 0.2 | 0.3 |
| 9. | | 2.1 | 1.0 | 0.8 | 0.4 | 0.4 |
| 19. | | 1.9 | 1.0 | 0.8 | 0.3 | 0.2 |
| | | 1.9 | 1.0 | 0.8 | 0.3 | 0.3 |
| 5. | High-2 | 2.5 | 1.0 | 0.9 | 0.6 | 0.6 |
| 12. | | 3.0 | 1.0 | 1.0 | 0.6 | 0.8 |
| 17. | | 2.9 | 1.0 | 0.9 | 0.8 | 0.7 |
| | | 2.8 | 1.0 | 0.9 | 0.7 | 0.7 |
| 7. | High-50 | 3.3 | 1.0 | 1.0 | 0.9 | 0.7 |
| 14. | | 3.6 | 1.0 | 1.0 | 1.0 | 0.7 |
| 20. | | 2.6 | 1.0 | 1.0 | 0.6 | 0.6 |
| | | 3.2 | 1.0 | 1.0 | 0.8 | 0.7 |
| 3. | High-100 | 3.2 | 1.0 | 1.0 | 0.7 | 0.8 |
| 13. | | 3.0 | 1.0 | 1.0 | 0.7 | 0.7 |
| 21. | | 2.9 | 1.0 | 1.0 | 0.8 | 0.3 |
| | | 3.0 | 1.0 | 1.0 | 0.7 | 0.6 |
| 4. | Idle | 2.2 | 1.0 | 1.0 | 0.7 | 0.2 |
| 10. | | 2.8 | 1.0 | 1.0 | 0.7 | 0.6 |
| 16 | | 2.9 | 1.0 | 1.0 | 0.7 | 0.4 |
| | | 2.6 | 1.0 | 1.0 | 0.7 | 0.4 |
| 24. | Idle-Acceleration | 3.4 | 1.0 | 1.0 | 0.7 | 0.7 |
| 26. | | 2.9 | 1.0 | 1.0 | 0.6 | 0.8 |
| 27. | | 2.7 | 1.0 | 0.9 | 0.7 | 0.4 |
| 32. | | 2.7 | 1.0 | 1.0 | 0.6 | 0.2 |
| | | 2.9 | 1.0 | 1.0 | 0.7 | 0.5 |
| 22. | Acceleration | 1.9 | 1.0 | 0.8 | 0.3 | 0.3 |
| 25. | | 2.3 | 1.0 | 0.9 | 0.6 | 0.3 |
| 29. | | 2.6 | 1.0 | 1.0 | 0.6 | 0.3 |
| 31. | | 2.7 | 1.0 | 0.9 | 0.7 | 0.4 |
| | | 2.4 | 1.0 | 0.9 | 0.6 | 0.3 |
| 23. | Deceleration | 2.1 | 1.0 | 0.9 | 0.6 | 0.2 |
| 28. | | 2.8 | 1.0 | 0.9 | 0.8 | 0.3 |
| 30. | | 2.4 | 1.0 | 0.8 | 0.6 | 0.6 |
| 33. | | 2.4 | 1.0 | 0.9 | 0.6 | 0.4 |
| | | 2.4 | 1.0 | 0.9 | 0.7 | 0.4 |
| | Cold Start | 3.3 | 1.0 | 1.0 | 0.9 | 0.7 |

## TABLE J-9. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Mercedes 300D Dilution Ratio: 100:1
Date: April 16, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 7. | Inter-2 | 2.7 | 1.0 | 0.9 | 0.8 | 0.6 |
| 11. | | 1.9 | 1.0 | 0.8 | 0.9 | 0.3 |
| 16. | | 2.3 | 1.0 | 0.8 | 0.8 | 0.5 |
| | | 2.3 | 1.0 | 0.8 | 0.8 | 0.5 |
| 4. | Inter-50 | 2.1 | 1.0 | 0.9 | 0.6 | 0.3 |
| 14 | | 2.2 | 1.0 | 1.0 | 0.5 | 0.4 |
| 20. | | 1.9 | 1.0 | 0.8 | 0.5 | 0.3 |
| | | 2.1 | 1.0 | 0.9 | 0.5 | 0.3 |
| 3. | Inter-100 | 2.3 | 1.0 | 1.0 | 0.5 | 0.3 |
| 13. | | 2.5 | 1.0 | 0.9 | 0.6 | 0.5 |
| 21. | | 1.5 | 1.0 | 0.9 | 0.4 | 0.1 |
| | | 2.1 | 1.0 | 0.9 | 0.5 | 0.3 |
| 5. | High-2 | 2.1 | 1.0 | 0.9 | 0.6 | 0.5 |
| 10. | | 2.1 | 1.0 | 0.8 | 0.9 | 0.4 |
| 17. | | 2.4 | 1.0 | 1.0 | 0.5 | 0.5 |
| | | 2.2 | 1.0 | 0.9 | 0.7 | 0.5 |
| 2. | High-50 | 2.8 | 1.0 | 1.0 | 0.6 | 0.5 |
| 8. | | 2.6 | 1.0 | 0.9 | 0.9 | 0.3 |
| 15. | | 2.9 | 1.0 | 1.0 | 0.5 | 0.6 |
| | | 2.8 | 1.0 | 1.0 | 0.7 | 0.5 |
| 1. | High-100 | 2.9 | 1.0 | 0.9 | 0.6 | 0.4 |
| 9. | | 2.0 | 1.0 | 0.9 | 0.5 | 0.3 |
| 19. | | 2.6 | 1.0 | 1.0 | 0.5 | 0.5 |
| | | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| 6. | Idle | 3.4 | 1.0 | 0.9 | 0.8 | 0.8 |
| 12. | | 2.8 | 1.0 | 0.8 | 0.8 | 0.5 |
| 18 | | 3.1 | 1.0 | 1.0 | 0.4 | 0.8 |
| | | 3.1 | 1.0 | 0.9 | 0.7 | 0.7 |
| 23. | Idle-Acceleration | 2.6 | 1.0 | 1.0 | 0.8 | 0.3 |
| 28. | | 2.6 | 1.0 | 1.0 | 0.6 | 0.6 |
| 29. | | 2.4 | 1.0 | 1.0 | 0.4 | 0.4 |
| 31. | | 2.8 | 1.0 | 0.9 | 0.6 | 0.5 |
| | | 2.6 | 1.0 | 1.0 | 0.6 | 0.5 |
| 24 | Acceleration | 2.8 | 1.0 | 0.9 | 0.8 | 0.6 |
| 26 | | 2.4 | 1.0 | 0.9 | 0.6 | 0.4 |
| 30. | | 2.8 | 1.0 | 0.9 | 0.8 | 0.5 |
| 33. | | 2.8 | 1.0 | 1.0 | 0.8 | 0.5 |
| | | 2.7 | 1.0 | 0.9 | 0.8 | 0.5 |
| 22. | Deceleration | 2.4 | 1.0 | 0.9 | 1.0 | 0.1 |
| 25. | | 2.6 | 1.0 | 0.9 | 0.8 | 0.4 |
| 27 | | 2.2 | 1.0 | 1.0 | 0.5 | 0.4 |
| 32. | | 3.3 | 1.0 | 1.0 | 0.8 | 0.6 |
| | | 2.6 | 1.0 | 1.0 | 0.8 | 0.4 |
| | Cold Start | 3.4 | 1.0 | 1.0 | 1.0 | 0.7 |

## TABLE J-10. ODOR SUMMARY -- PEUGEOT 204D EVALUATION
### 100: 1 DILUTION

| Operating Condition | Load | Date | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|---|
| 2100 rpm | 2% | 3/29/76 | 3.3 | 1.0 | 1.0 | 0.7 | 0.8 |
| | | 3/31/76 | 3.5 | 1.1 | 0.9 | 0.9 | 0.8 |
| | | 4/2/76 | 3.2 | 1.0 | 1.0 | 0.8 | 0.9 |
| | | Average | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| 2100 rpm<br>33 mph | 50% | 3/29/76 | 3.5 | 1.0 | 1.0 | 0.8 | 0.7 |
| | | 3/31/76 | 3.4 | 1.0 | 1.0 | 0.9 | 1.0 |
| | | 4/2/76 | 3.3 | 1.0 | 1.0 | 1.0 | 0.8 |
| | | Average | 3.4 | 1.0 | 1.0 | 0.9 | 0.8 |
| 2100 rpm<br>33 mph | 100% | 3/29/76 | 3.8 | 1.1 | 1.0 | 0.9 | 0.9 |
| | | 3/31/76 | 4.6 | 1.4 | 1.1 | 1.0 | 1.0 |
| | | 4/2/76 | 4.0 | 1.1 | 1.0 | 1.0 | 1.0 |
| | | Average | 4.1 | 1.2 | 1.0 | 1.0 | 1.0 |
| 3500 rpm | 2% | 3/29/76 | 2.7 | 1.0 | 0.9 | 0.6 | 0.6 |
| | | 3/31/76 | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| | | 4/2/76 | 2.9 | 1.0 | 1.0 | 0.8 | 0.8 |
| | | Average | 3.0 | 1.0 | 1.0 | 0.7 | 0.7 |
| 3500 rpm<br>56 mph | 50% | 3/29/76 | 3.2 | 1.0 | 1.0 | 0.8 | 0.8 |
| | | 3/31/76 | 3.0 | 1.0 | 1.0 | 0.7 | 0.7 |
| | | 4/2/76 | 3.3 | 1.0 | 1.0 | 0.8 | 0.7 |
| | | Average | 3.2 | 1.0 | 1.0 | 0.8 | 0.7 |
| 3500 rpm<br>56 mph | 100% | 3/29/76 | 3.7 | 1.0 | 1.0 | 0.9 | 0.7 |
| | | 3/31/76 | 3.5 | 1.1 | 1.0 | 0.9 | 0.9 |
| | | 4/2/76 | 3.7 | 1.0 | 1.0 | 0.8 | 1.0 |
| | | Average | 3.6 | 1.0 | 1.0 | 0.9 | 0.9 |
| Idle | | 3/29/76 | 3.8 | 1.0 | 1.0 | 0.8 | 0.9 |
| | | 3/31/76 | 3.9 | 1.1 | 0.9 | 1.0 | 0.7 |
| | | 4/2/76 | 3.8 | 1.0 | 1.0 | 0.9 | 1.0 |
| | | Average | 3.8 | 1.0 | 1.0 | 0.9 | 0.8 |
| Idle-Acceleration | | 3/29/76 | 3.8 | 1.1 | 1.0 | 0.9 | 0.8 |
| | | 3/31/76 | 3.7 | 1.1 | 1.0 | 0.9 | 0.8 |
| | | 4/2/76 | 3.9 | 1.0 | 1.0 | 0.9 | 1.0 |
| | | Average | 3.8 | 1.1 | 1.0 | 0.9 | 0.9 |
| Acceleration | | 3/29/76 | 3.6 | 1.1 | 1.0 | 0.9 | 0.9 |
| | | 3/31/76 | 3.7 | 1.1 | 1.0 | 0.9 | 0.9 |
| | | 4/2/76 | 4.2 | 1.2 | 1.0 | 1.0 | 1.0 |
| | | Average | 3.8 | 1.1 | 1.0 | 0.9 | 0.9 |
| Deceleration | | 3/29/76 | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |
| | | 3/31/76 | 3.0 | 1.0 | 1.0 | 0.7 | 0.7 |
| | | 4/2/76 | 3.5 | 1.0 | 1.0 | 0.8 | 0.9 |
| | | Average | 3.1 | 1.0 | 1.0 | 0.7 | 0.7 |
| Cold Start | | 3/29/76 | 3.6 | 1.0 | 1.0 | 0.8 | 0.6 |
| | | 3/31/76 | 2.6 | 1.0 | 1.0 | 0.5 | 0.5 |
| | | 4/2/76 | 4.0 | 1.0 | 1.0 | 0.9 | 1.0 |
| | | Average | 3.4 | 1.0 | 1.0 | 0.7 | 0.7 |

## TABLE J-11. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Peugeot 204D
Date: March 29, 1976

Dilution Ratio: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 4. | Inter-2 | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| 10. | | 3.7 | 1.0 | 0.9 | 0.8 | 0.9 |
| 15. | | 3.0 | 1.0 | 1.0 | 0.5 | 0.8 |
| | | 3.3 | 1.0 | 1.0 | 0.7 | 0.8 |
| 3. | Inter-50 | 4.4 | 1.0 | 1.1 | 1.0 | 1.1 |
| 12. | | 2.9 | 1.0 | 1.0 | 0.6 | 0.5 |
| 17. | | 3.1 | 1.0 | 0.9 | 0.9 | 0.6 |
| | | 3.5 | 1.0 | 1.0 | 0.8 | 0.7 |
| 1. | Inter-100 | 4.0 | 1.1 | 1.0 | 0.8 | 0.9 |
| 9. | | 4.1 | 1.0 | 1.0 | 1.0 | 0.9 |
| 16. | | 3.3 | 1.1 | 1.0 | 0.8 | 1.0 |
| | | 3.8 | 1.1 | 1.0 | 0.9 | 0.9 |
| 8. | High-2 | 3.1 | 1.0 | 0.9 | 0.8 | 0.8 |
| 13. | | 2.6 | 1.0 | 0.9 | 0.5 | 0.8 |
| 20. | | 2.5 | 1.0 | 1.0 | 0.6 | 0.3 |
| | | 2.7 | 1.0 | 0.9 | 0.6 | 0.6 |
| 5. | High-50 | 3.5 | 1.0 | 1.0 | 0.9 | 0.8 |
| 14. | | 3.4 | 1.0 | 1.0 | 0.9 | 0.9 |
| 21. | | 2.8 | 1.0 | 1.0 | 0.5 | 0.6 |
| | | 3.2 | 1.0 | 1.0 | 0.8 | 0.8 |
| 6. | High-100 | 3.8 | 1.0 | 1.0 | 0.9 | 0.6 |
| 11. | | 4.0 | 1.1 | 1.0 | 0.9 | 0.8 |
| 18. | | 3.3 | 1.0 | 1.0 | 0.9 | 0.6 |
| | | 3.7 | 1.0 | 1.0 | 0.9 | 0.7 |
| 2. | Idle | 3.5 | 1.0 | 0.9 | 0.6 | 0.8 |
| 7. | | 3.8 | 1.1 | 1.0 | 0.8 | 0.5 |
| 19. | | 4.0 | 1.0 | 1.0 | 0.9 | 1.1 |
| | | 3.8 | 1.0 | 1.0 | 0.8 | 0.8 |
| 24. | Idle-Acceleration | 3.9 | 1.3 | 1.0 | 0.9 | 0.8 |
| 27. | | 3.9 | 1.1 | 1.0 | 1.0 | 0.8 |
| 30. | | 3.5 | 1.0 | 1.0 | 0.8 | 0.6 |
| 32. | | 4.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | 3.8 | 1.1 | 1.0 | 0.9 | 0.8 |
| 23. | Acceleration | 4.0 | 1.3 | 1.0 | 1.0 | 1.0 |
| 25. | | 3.4 | 1.0 | 1.0 | 0.9 | 0.8 |
| 28. | | 3.6 | 1.0 | 1.0 | 0.9 | 1.0 |
| 33. | | 3.3 | 1.0 | 1.0 | 0.8 | 0.6 |
| | | 3.6 | 1.1 | 1.0 | 0.9 | 0.9 |
| 22. | Deceleration | 2.5 | 1.0 | 0.9 | 0.6 | 0.4 |
| 26. | | 2.6 | 0.9 | 1.0 | 0.5 | 0.5 |
| 29. | | 3.5 | 1.0 | 1.0 | 0.8 | 0.8 |
| 31. | | 2.8 | 1.0 | 1.0 | 0.4 | 0.6 |
| | | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |
| | Cold Start | 3.6 | 1.0 | 1.0 | 0.8 | 0.6 |

TABLE J-12. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Peugeot 204D Dilution Ratio: 100:1
Date: March 31, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 5. | Inter-2 | 3.6 | 1.1 | 1.0 | 1.0 | 1.0 |
| 11. | | 3.3 | 1.0 | 0.8 | 1.0 | 0.6 |
| 14. | | 3.6 | 1.1 | 1.0 | 0.7 | 0.8 |
| | | 3.5 | 1.1 | 0.9 | 0.9 | 0.8 |
| 4. | Inter-50 | 3.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| 10. | | 3.3 | 1.0 | 1.0 | 0.8 | 0.9 |
| 17. | | 3.4 | 1.0 | 1.0 | 0.8 | 1.0 |
| | | 3.4 | 1.0 | 1.0 | 0.9 | 1.0 |
| 8. | Inter-100 | 5.4 | 1.8 | 1.3 | 0.9 | 1.3 |
| 15. | | 4.8 | 1.4 | 1.0 | 1.0 | 1.0 |
| 21. | | 3.6 | 1.0 | 1.0 | 1.0 | 0.8 |
| | | 4.6 | 1.4 | 1.1 | 1.0 | 1.0 |
| 3. | High-2 | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| 6. | | 3.9 | 1.0 | 1.0 | 0.9 | 1.0 |
| 18. | | 2.8 | 1.0 | 1.0 | 0.7 | 0.5 |
| | | 3.3 | 1.0 | 1.0 | 0.8 | 0.8 |
| 2. | High-50 | 2.8 | 1.0 | 1.0 | 0.8 | 0.5 |
| 12. | | 3.0 | 0.9 | 1.0 | 0.8 | 0.6 |
| 19. | | 3.3 | 1.0 | 1.0 | 0.6 | 0.9 |
| | | 3.0 | 1.0 | 1.0 | 0.7 | 0.7 |
| 1. | High-100 | 3.4 | 1.0 | 1.0 | 0.9 | 0.7 |
| 9. | | 2.8 | 1.0 | 1.0 | 0.9 | 0.9 |
| 16. | | 4.4 | 1.4 | 1.0 | 0.8 | 1.1 |
| | | 3.5 | 1.1 | 1.0 | 0.9 | 0.9 |
| 7. | Idle | 4.3 | 1.3 | 1.0 | 0.9 | 0.9 |
| 13. | | 4.0 | 1.1 | 1.0 | 1.0 | 0.6 |
| 20. | | 3.3 | 1.0 | 0.8 | 1.0 | 0.6 |
| | | 3.9 | 1.1 | 0.9 | 1.0 | 0.7 |
| 23. | Idle-Acceleration | 4.6 | 1.3 | 1.0 | 0.9 | 1.0 |
| 28. | | 3.3 | 1.1 | 1.0 | 0.8 | 0.9 |
| 30. | | 2.9 | 1.0 | 1.0 | 0.9 | 0.6 |
| 32. | | 3.8 | 1.1 | 1.0 | 0.9 | 0.8 |
| | | 3.7 | 1.1 | 1.0 | 0.9 | 0.8 |
| 24. | Acceleration | 3.8 | 1.0 | 1.0 | 1.0 | 0.9 |
| 27. | | 3.9 | 1.1 | 1.0 | 0.8 | 1.1 |
| 29. | | 3.3 | 1.0 | 1.0 | 0.9 | 0.7 |
| 33. | | 3.6 | 1.1 | 1.0 | 1.0 | 0.7 |
| | | 3.7 | 1.1 | 1.0 | 0.9 | 0.9 |
| 22. | Deceleration | 3.4 | 1.0 | 1.0 | 0.9 | 0.9 |
| 25. | | 2.6 | 1.0 | 0.9 | 0.6 | 0.6 |
| 26. | | 2.9 | 1.1 | 1.0 | 0.6 | 0.6 |
| 31. | | 3.0 | 1.0 | 0.9 | 0.6 | 0.7 |
| | | 3.0 | 1.0 | 1.0 | 0.7 | 0.7 |
| | Cold Start | 2.6 | 1.0 | 1.0 | 0.5 | 0.5 |

## TABLE J-13. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Peugeot 204D
Date: April 2, 1976
Dilution Ratio: 100:1

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 7. | Inter-2 | 3.1 | 1.0 | 1.0 | 0.7 | 0.9 |
| 12. | | 2.6 | 1.0 | 1.0 | 0.6 | 1.0 |
| 18. | | 3.9 | 1.1 | 1.0 | 1.0 | 0.9 |
| | | 3.2 | 1.0 | 1.0 | 0.8 | 0.9 |
| 5. | Inter-50 | 3.0 | 1.0 | 1.0 | 0.9 | 0.6 |
| 10. | | 2.9 | 1.0 | 1.0 | 1.0 | 1.0 |
| 19. | | 3.9 | 1.0 | 1.0 | 1.0 | 0.9 |
| | | 3.3 | 1.0 | 1.0 | 1.0 | 0.8 |
| 6. | Inter-100 | 4.4 | 1.1 | 1.0 | 1.0 | 1.0 |
| 13. | | 4.0 | 1.1 | 1.0 | 1.0 | 1.0 |
| 21. | | 3.7 | 1.0 | 1.0 | 1.0 | 1.0 |
| | | 4.0 | 1.1 | 1.0 | 1.0 | 1.0 |
| 2. | High-2 | 2.7 | 1.0 | 1.0 | 0.7 | 0.6 |
| 9. | | 3.1 | 1.0 | 1.0 | 0.9 | 1.0 |
| 14. | | 3.0 | 1.0 | 1.0 | 0.7 | 0.7 |
| | | 2.9 | 1.0 | 1.0 | 0.8 | 0.8 |
| 1. | High-50 | 3.4 | 1.0 | 1.0 | 0.7 | 0.7 |
| 8. | | 3.0 | 1.0 | 1.0 | 0.6 | 0.7 |
| 17. | | 3.4 | 1.0 | 1.0 | 1.0 | 0.6 |
| | | 3.3 | 1.0 | 1.0 | 0.8 | 0.7 |
| 4. | High-100 | 3.7 | 1.1 | 1.0 | 1.0 | 1.0 |
| 11. | | 4.3 | 1.0 | 1.0 | 1.0 | 1.0 |
| 16. | | 3.0 | 1.0 | 1.0 | 0.4 | 1.0 |
| | | 3.7 | 1.0 | 1.0 | 0.8 | 1.0 |
| 3. | Idle | 3.9 | 1.0 | 1.0 | 1.0 | 1.0 |
| 15. | | 3.9 | 1.0 | 0.9 | 1.0 | 1.0 |
| 20. | | 3.6 | 1.0 | 1.0 | 0.7 | 0.9 |
| | | 3.8 | 1.0 | 1.0 | 0.9 | 1.0 |
| 23. | Idle-Acceleration | 4.0 | 1.0 | 1.0 | 0.9 | 1.0 |
| 25. | | 3.4 | 1.0 | 1.0 | 0.9 | 0.9 |
| 28. | | 4.0 | 1.1 | 1.0 | 1.0 | 1.0 |
| 31. | | 4.3 | 1.0 | 1.0 | 0.9 | 1.0 |
| | | 3.9 | 1.0 | 1.0 | 0.9 | 1.0 |
| 22. | Acceleration | 3.9 | 1.0 | 1.0 | 0.9 | 1.0 |
| 27. | | 4.7 | 1.4 | 1.0 | 1.0 | 1.1 |
| 30. | | 4.1 | 1.3 | 1.0 | 1.0 | 1.0 |
| 32. | | 3.9 | 1.1 | 1.0 | 0.9 | 1.0 |
| | | 4.2 | 1.2 | 1.0 | 1.0 | 1.0 |
| 24. | Deceleration | 3.0 | 1.0 | 1.0 | 0.9 | 0.7 |
| 26. | | 3.4 | 1.0 | 1.0 | 0.7 | 0.9 |
| 29. | | 3.7 | 1.1 | 1.0 | 0.7 | 0.9 |
| 33. | | 4.0 | 1.0 | 1.0 | 0.9 | 0.9 |
| | | 3.5 | 1.0 | 1.0 | 0.8 | 0.9 |
| | Cold Start | 4.0 | 1.0 | 1.0 | 0.9 | 1.0 |

## TABLE J-14. ODOR SUMMARY -- PERKINS 6-247 ENGINE, IHC PICK-UP TRUCK EVALUATION 100:1 DILUTION

| Operating Condition | Load | Date | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|---|
| 1620 rpm | 2% | 4/29/76 | 4.5 | 1.3 | 1.0 | 0.8 | 1.1 |
| | | 4/30/76 | 4.7 | 1.4 | 1.2 | 0.9 | 1.0 |
| | | Average | 4.6 | 1.4 | 1.1 | 0.9 | 1.1 |
| 1620 rpm | 50% | 4/28/76 | 2.7 | 1.0 | 1.0 | 0.7 | 0.3 |
| 33 mph | | 4/30/76 | 3.1 | 1.0 | 1.0 | 0.5 | 0.6 |
| | | Average | 2.9 | 1.0 | 1.0 | 0.6 | 0.5 |
| 1620 rpm | 100% | 4/28/76 | 3.9 | 1.1 | 1.1 | 0.8 | 0.9 |
| 33 mph | | 4/30/76 | 3.5 | 1.1 | 0.9 | 0.8 | 0.8 |
| | | Average | 3.7 | 1.1 | 1.0 | 0.8 | 0.9 |
| 2700 rpm | 2% | 4/28/76 | 4.6 | 1.4 | 1.1 | 0.9 | 1.0 |
| | | 4/30/76 | 5.1 | 1.4 | 1.2 | 0.9 | 1.1 |
| | | Average | 4.9 | 1.4 | 1.2 | 0.9 | 1.1 |
| 2700 rpm | 50% | 4/28/76 | 3.2 | 1.4 | 1.1 | 0.9 | 1.0 |
| 56 mph | | 4/20/76 | 3.4 | 1.0 | 1.0 | 0.6 | 0.7 |
| | | Average | 3.3 | 1.2 | 1.1 | 0.8 | 0.9 |
| 2700 rpm | 100% | 4/28/76 | 4.1 | 1.1 | 1.0 | 0.9 | 1.0 |
| 56 mph | | 4/30/76 | 3.4 | 1.1 | 1.0 | 0.6 | 0.8 |
| | | Average | 3.8 | 1.1 | 1.0 | 0.8 | 0.9 |
| Idle | | 4/28/76 | 4.4 | 1.3 | 1.1 | 0.9 | 0.9 |
| | | 4/30/76 | 3.9 | 1.2 | 1.1 | 0.9 | 0.8 |
| | | Average | 4.2 | 1.3 | 1.1 | 0.9 | 0.9 |
| Idle-Acceleration | | 4/28/76 | 4.2 | 1.1 | 1.0 | 0.9 | 1.0 |
| | | 4/30/76 | 4.5 | 1.3 | 1.1 | 0.9 | 1.0 |
| | | Average | 4.4 | 1.2 | 1.1 | 0.9 | 1.0 |
| Acceleration | | 4/28/76 | 4.2 | 1.2 | 1.0 | 0.9 | 0.9 |
| | | 4/30/76 | 3.8 | 1.2 | 1.0 | 0.7 | 0.8 |
| | | Average | 4.0 | 1.2 | 1.0 | 0.8 | 0.9 |
| Deceleration | | 4/28/76 | 3.4 | 1.1 | 1.0 | 0.9 | 0.7 |
| | | 4/30/76 | 3.1 | 1.0 | 1.0 | 0.8 | 0.5 |
| | | Average | 3.3 | 1.1 | 1.0 | 0.9 | 0.6 |
| Cold Start | | 4/28/76 | 4.8 | 1.6 | 1.1 | 0.9 | 1.0 |
| | | 4/30/76 | 4.1 | 1.3 | 1.0 | 0.9 | 0.9 |
| | | Average | 4.5 | 1.5 | 1.1 | 0.9 | 1.0 |

## TABLE J-15. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: IHC Pick-up, Perkins 6-247 Engine Dilution Ratio: 100:1
Date: April 28, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 7. | Inter-2 | 4.6 | 1.4 | 1.1 | 0.7 | 1.2 |
| 11. | | 4.8 | 1.4 | 1.0 | 0.9 | 1.1 |
| 16. | | 4.2 | 1.2 | 1.0 | 0.8 | 1.1 |
| | | 4.5 | 1.3 | 1.0 | 0.8 | 1.1 |
| 4. | Inter-50 | 2.8 | 1.0 | 1.0 | 0.8 | 0.3 |
| 14. | | 2.2 | 1.0 | 1.0 | 0.4 | 0.2 |
| 20. | | 3.1 | 1.0 | 1.0 | 0.8 | 0.4 |
| | | 2.7 | 1.0 | 1.0 | 0.7 | 0.3 |
| 3. | Inter-100 | 3.1 | 1.0 | 1.0 | 0.8 | 0.6 |
| 13. | | 4.9 | 1.3 | 1.2 | 0.9 | 1.4 |
| 21. | | 3.7 | 1.0 | 1.0 | 0.8 | 0.8 |
| | | 3.9 | 1.1 | 1.1 | 0.8 | 0.9 |
| 5. | High-2 | 5.1 | 1.7 | 1.1 | 0.8 | 1.2 |
| 10. | | 4.5 | 1.1 | 1.1 | 0.9 | 1.1 |
| 17. | | 4.2 | 1.3 | 1.0 | 0.9 | 0.8 |
| | | 4.6 | 1.4 | 1.1 | 0.9 | 1.0 |
| 2. | High-50 | 3.3 | 1.0 | 1.0 | 0.9 | 0.6 |
| 8. | | 3.6 | 1.0 | 1.0 | 0.9 | 0.7 |
| 15. | | 2.8 | 1.0 | 1.0 | 0.7 | 0.2 |
| | | 3.2 | 1.0 | 1.0 | 0.8 | 0.5 |
| 1. | High-100 | 4.1 | 1.1 | 0.9 | 0.9 | 1.1 |
| 9. | | 4.2 | 1.2 | 1.1 | 0.8 | 1.0 |
| 19. | | 4.1 | 1.1 | 1.0 | 1.0 | 0.8 |
| | | 4.1 | 1.1 | 1.0 | 0.9 | 1.0 |
| 6. | Idle | 4.0 | 1.3 | 1.1 | 0.8 | 0.8 |
| 12. | | 4.4 | 1.3 | 1.1 | 0.8 | 1.1 |
| 18. | | 4.7 | 1.3 | 1.0 | 1.0 | 0.9 |
| | | 4.4 | 1.3 | 1.1 | 0.9 | 0.9 |
| 23. | Idle-Acceleration | 3.8 | 1.1 | 1.0 | 0.7 | 1.0 |
| 28. | | 4.4 | 1.3 | 1.0 | 0.9 | 1.0 |
| 29. | | 4.1 | 1.0 | 1.0 | 0.9 | 0.9 |
| 31. | | 4.3 | 1.1 | 1.1 | 0.9 | 1.0 |
| | | 4.2 | 1.1 | 1.0 | 0.9 | 1.0 |
| 24. | Acceleration | 3.9 | 1.1 | 1.1 | 0.8 | 0.9 |
| 26. | | 4.6 | 1.4 | 1.0 | 0.9 | 0.9 |
| 30. | | 4.4 | 1.3 | 1.0 | 0.8 | 1.1 |
| 33. | | 3.9 | 1.0 | 1.0 | 0.9 | 0.8 |
| | | 4.2 | 1.2 | 1.0 | 0.9 | 0.9 |
| 22. | Deceleration | 2.8 | 1.0 | 0.9 | 0.8 | 0.4 |
| 25. | | 3.3 | 1.0 | 1.0 | 0.9 | 0.7 |
| 27. | | 3.6 | 1.1 | 1.0 | 0.8 | 0.9 |
| 32. | | 3.9 | 1.1 | 1.0 | 1.0 | 0.7 |
| | | 3.4 | 1.1 | 1.0 | 0.9 | 0.7 |
| | Cold Start | 4.8 | 1.6 | 1.1 | 0.9 | 1.0 |

## TABLE J-16. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: IHC Pick-up, Perkins 6-247 Engine Dilution Ratio: 100:1
Date: April 30, 1976

| Run No. | Operating Condition | "D" Composite | "B" Burnt | "O" Oily | "A" Aromatic | "P" Pungent |
|---|---|---|---|---|---|---|
| 6. | Inter-2 | 4.7 | 1.4 | 1.0 | 1.0 | 1.0 |
| 11. | | 4.9 | 1.4 | 1.4 | 0.7 | 1.1 |
| 15. | | 4.4 | 1.3 | 1.1 | 0.9 | 1.0 |
| | | 4.7 | 1.4 | 1.2 | 0.9 | 1.0 |
| 2. | Inter-50 | 2.6 | 1.0 | 1.0 | 0.5 | 0.4 |
| 8. | | 2.7 | 1.0 | 1.0 | 0.4 | 0.6 |
| 18. | | 4.0 | 1.1 | 1.0 | 0.7 | 0.9 |
| | | 3.1 | 1.0 | 1.0 | 0.5 | 0.6 |
| 1. | Inter-100 | 3.3 | 1.1 | 0.9 | 1.0 | 0.7 |
| 9. | | 3.0 | 1.0 | 1.0 | 0.6 | 0.7 |
| 19. | | 4.1 | 1.1 | 0.9 | 0.9 | 1.1 |
| | | 3.5 | 1.1 | 0.9 | 0.8 | 0.8 |
| 5. | High-2 | 4.9 | 1.6 | 1.1 | 0.9 | 1.1 |
| 12. | | 5.2 | 1.4 | 1.3 | 0.9 | 1.1 |
| 17. | | 5.3 | 1.3 | 1.3 | 1.0 | 1.1 |
| | | 5.1 | 1.4 | 1.2 | 0.9 | 1.1 |
| 7. | High-50 | 4.0 | 1.1 | 1.1 | 0.6 | 0.9 |
| 14. | | 3.0 | 1.0 | 1.0 | 0.4 | 0.6 |
| 20. | | 3.1 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 3.4 | 1.0 | 1.0 | 0.6 | 0.7 |
| 3. | High-100 | 2.9 | 1.0 | 1.0 | 0.6 | 0.6 |
| 13. | | 4.0 | 1.1 | 1.0 | 0.7 | 0.9 |
| 21. | | 3.3 | 1.1 | 1.1 | 0.4 | 0.9 |
| | | 3.4 | 1.1 | 1.0 | 0.4 | 0.8 |
| 4. | Idle | 3.9 | 1.3 | 1.0 | 0.9 | 0.9 |
| 10. | | 3.6 | 1.0 | 1.0 | 1.0 | 0.7 |
| 16. | | 4.1 | 1.3 | 1.3 | 0.9 | 0.9 |
| | | 3.9 | 1.2 | 1.1 | 0.9 | 0.8 |
| 24. | Idle-Acceleration | 4.7 | 1.4 | 1.0 | 0.9 | 1.0 |
| 26. | | 4.6 | 1.3 | 1.0 | 1.0 | 1.0 |
| 27. | | 4.1 | 1.3 | 1.0 | 0.9 | 1.0 |
| 32. | | 4.4 | 1.3 | 1.3 | 0.7 | 1.1 |
| | | 4.5 | 1.3 | 1.1 | 0.9 | 1.0 |
| 22. | Acceleration | 3.3 | 1.3 | 0.9 | 0.4 | 1.0 |
| 25. | | 4.1 | 1.1 | 1.0 | 0.9 | 1.0 |
| 29. | | 3.4 | 1.0 | 1.0 | 0.7 | 0.6 |
| 31. | | 4.4 | 1.3 | 1.1 | 0.9 | 0.7 |
| | | 3.8 | 1.2 | 1.0 | 0.7 | 0.8 |
| 23. | Deceleration | 2.7 | 1.0 | 0.9 | 0.9 | 0.4 |
| 28. | | 2.9 | 1.0 | 1.0 | 0.7 | 0.4 |
| 30. | | 3.6 | 1.1 | 0.9 | 1.0 | 0.6 |
| 33. | | 3.0 | 1.0 | 1.0 | 0.7 | 0.6 |
| | | 3.1 | 1.0 | 1.0 | 0.8 | 0.5 |
| | Cold Start | 4.1 | 1.3 | 1.0 | 0.9 | 0.9 |

# APPENDIX K

## INSTRUMENTAL-WET CHEMICAL EXHAUST DATA TAKEN DURING ODOR TEST OF FIVE LD DIESEL VEHICLES

## TABLE K-1. EMISSIONS OBTAINED SIMULTANEOUSLY WITH ODOR RATINGS -- MERCEDES 220D COMPREX EVALUATION

| | | | | | NDIR | C. L. | | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Load | Date | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, µg/l | LCO, µg/l | TIA |
| 1680 rpm | 2% | 4/07/76 | 53 | 157 | 100 | 105 | 113 | 2.9 | 14.9 | 7.2 | 1.9 |
| | | 4/09/76 | 63 | 135 | 140 | 118 | 126 | 2.9 | 8.5 | 4.5 | 1.7 |
| | | Average | 58 | 146 | 120 | 112 | 120 | 2.9 | 11.7 | 5.9 | 1.8 |
| 1680 rpm<br>32 mph | 50% | 4/07/76 | 32 | 131 | 257 | 253 | 258 | 5.6 | 16.4 | 7.9 | 1.9 |
| | | 4/09/76 | 33 | 128 | 284 | 249 | 253 | 5.8 | 8.1 | 4.4 | 1.6 |
| | | Average | 33 | 130 | 271 | 251 | 256 | 5.7 | 12.3 | 6.2 | 1.8 |
| 1680 rpm<br>32 mph | 100% | 4/07/76 | 50 | 2247 | 163 | 172 | 173 | 6.6 | 10.3 | 5.4 | 1.8 |
| | | 4/09/76 | 33 | 2557 | 199 | 171 | 173 | 6.7 | 7.0 | 4.5 | 1.7 |
| | | Average | 42 | 2402 | 181 | 172 | 173 | 6.7 | 8.7 | 5.0 | 1.8 |
| 2800 rpm | 2% | 4/07/76 | 167 | 417 | 128 | 125 | 138 | 3.8 | 30.7 | 11.1 | 2.1 |
| | | 4/09/76 | 172 | 413 | 149 | 116 | 124 | 3.8 | 16.0 | 5.4 | 1.7 |
| | | Average | 170 | 415 | 139 | 121 | 131 | 3.8 | 23.4 | 8.3 | 1.9 |
| 2800 rpm<br>56 mph | 50% | 4/07/76 | 49 | 144 | 357 | 335 | 338 | 6.0 | 12.7 | 6.8 | 1.9 |
| | | 4/09/76 | 43 | 147 | 371 | 333 | 336 | 6.1 | 10.0 | 5.8 | 1.7 |
| | | Average | 46 | 146 | 364 | 334 | 337 | 6.1 | 11.4 | 6.3 | 1.8 |
| 2800 rpm<br>56 mph | 100% | 4/07/76 | 48 | 1483 | 329 | 325 | 325 | 8.0 | 28.0 | 15.0 | 2.1 |
| | | 4/09/76 | 28 | 2349 | 343 | 300 | 306 | 8.0 | 6.4 | 4.9 | 1.7 |
| | | Average | 38 | 1916 | 336 | 313 | 316 | 8.0 | 17.2 | 10.0 | 1.9 |
| Idle | | 4/07/76 | 108 | 171 | 141 | 138 | 148 | 3.1 | 25.2 | 10.8 | 2.0 |
| | | 4/09/76 | 95 | 137 | 159 | 127 | 130 | 2.9 | 6.7 | 3.6 | 1.5 |
| | | Average | 102 | 154 | 150 | 133 | 139 | 3.0 | 16.0 | 7.2 | 1.8 |

## TABLE K-2. GASEOUS EMISSIONS SUMMARY

Vehicle: Mercedes 220D Comprex Date: April 7, 1976

| | | | | NDIR | C. L. | | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Operating Condition | HC, ppm | CO, ppm | NO, ppm | NO, ppm | NO$_x$, ppm | CO$_2$, % | LCA, μg/l | LCO, μg/l | TIA |
| 1. | Inter-2 | 108 | 157 | 80 | 90 | 100 | 3.0 | 19.0 | 8.9 | 2.0 |
| 8. | | 64 | 170 | 122 | 110 | 120 | 2.9 | 16.9 | 7.4 | 1.9 |
| 14. | | 48 | 144 | 99 | 115 | 120 | 2.9 | 8.8 | 5.2 | 1.7 |
| | | 53 | 157 | 100 | 105 | 113 | 2.9 | 14.9 | 7.2 | 1.9 |
| 6. | Inter-50 | 36 | 91 | 276 | 250 | 255 | 5.6 | 24.5 | 11.7 | 2.0 |
| 13. | | 28 | 144 | 235 | 260 | 260 | 5.5 | 13.3 | 6.1 | 1.8 |
| 19. | | 32 | 157 | 259 | 250 | 260 | 5.8 | 11.3 | 5.8 | 1.8 |
| | | 32 | 131 | 257 | 253 | 258 | 5.6 | 16.4 | 7.9 | 1.9 |
| 5. | Inter-100 | 56 | 2116 | 198 | 175 | 175 | 6.6 | ---- | --- | --- |
| 12. | | 48 | 2247 | 122 | 165 | 170 | 6.6 | 11.9 | 6.3 | 1.8 |
| 20. | | 48 | 2378 | 170 | 175 | 175 | 6.6 | 8.6 | 4.4 | 1.7 |
| | | 50 | 2247 | 163 | 172 | 173 | 6.6 | 10.3 | 5.4 | 1.8 |
| 4. | High-2 | 172 | 385 | 146 | 125 | 135 | 3.7 | 34.2 | 12.6 | 2.2 |
| 10 | | 152 | 512 | 119 | 140 | 155 | 3.8 | 34.8 | 13.1 | 2.1 |
| 16. | | 176 | 453 | 119 | 110 | 125 | 3.8 | 23.1 | 7.7 | 1.9 |
| | | 167 | 417 | 128 | 125 | 138 | 3.8 | 30.7 | 11.1 | 2.1 |
| 7. | High-50 | 48 | 118 | 352 | 325 | 325 | 5.9 | ---- | --- | --- |
| 15. | | 56 | 157 | 360 | 330 | 335 | 6.0 | 14.5 | 7.6 | 1.9 |
| 21. | | 44 | 157 | 360 | 350 | 355 | 6.1 | 10.8 | 5.9 | 1.8 |
| | | 49 | 144 | 357 | 335 | 338 | 6.0 | 12.7 | 6.8 | 1.9 |
| 2. | High-100 | 80 | 1861 | 343 | 320 | 320 | 8.2 | 44.6 | 22.6 | 2.4 |
| 9. | | 32 | 1190 | 284 | 320 | 320 | 7.9 | 25.9 | 13.7 | 2.1 |
| 17. | | 32 | 1398 | 360 | 335 | 335 | 8.0 | 13.4 | 8.7 | 1.9 |
| | | 48 | 1483 | 329 | 325 | 325 | 8.0 | 28.0 | 15.0 | 2.1 |
| 3. | Idle | 104 | 131 | 174 | 150 | 160 | 3.1 | 38.5 | 16.8 | 2.2 |
| 11. | | 124 | 197 | 95 | 125 | 130 | 3.0 | 21.7 | 9.1 | 2.0 |
| 18. | | 96 | 184 | 154 | 140 | 155 | 3.1 | 15.4 | 6.5 | 1.8 |
| | | 108 | 171 | 141 | 138 | 148 | 3.1 | 25.2 | 10.8 | 2.0 |

## TABLE K-3. GASEOUS EMISSIONS SUMMARY

Vehicle: Mercedes 220D Comprex

Date: April 9, 1976

|  |  |  |  | NDIR | C. L. |  |  | DOAS Results |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Operating Condition | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, µg/l | LCO, µg/l | TIA |
| 8. | Inter-2 | 88 | 170 | 104 | 87 | 96 | 3.0 | 8.1 | 4.5 | 1.7 |
| 14. |  | 44 | 118 | 162 | 133 | 138 | 2.8 | 8.9 | 4.5 | 1.6 |
| 21. |  | 56 | 118 | 154 | 135 | 143 | 2.8 | --- | --- | --- |
|  |  | 63 | 135 | 140 | 118 | 126 | 2.9 | 8.5 | 4.5 | 1.7 |
| 3. | Inter-50 | 22 | 122 | 276 | 245 | 248 | 5.6 | 10.0 | 5.5 | 1.7 |
| 9. |  | 48 | 131 | 276 | 242 | 249 | 5.7 | 7.3 | 4.2 | 1.6 |
| 16. |  | 28 | 131 | 301 | 260 | 263 | 5.9 | 6.9 | 3.5 | 1.5 |
|  |  | 33 | 128 | 284 | 249 | 253 | 5.8 | 8.1 | 4.4 | 1.6 |
| 2. | Inter-100 | 24 | 2512 | 194 | 171 | 173 | 6.5 | 13.0 | 5.7 | 1.8 |
| 10. |  | 44 | 2580 | 193 | 172 | 173 | 6.7 | 5.9 | 4.5 | 1.7 |
| 17. |  | 30 | 2580 | 210 | 170 | 173 | 6.9 | 2.1 | 3.3 | 1.5 |
|  |  | 33 | 2557 | 199 | 171 | 173 | 6.7 | 7.0 | 4.5 | 1.7 |
| 6. | High-2 | 152 | 398 | 178 | 133 | 140 | 3.9 | 18.2 | 6.3 | 1.8 |
| 12. |  | 176 | 389 | 130 | 100 | 113 | 3.6 | 13.3 | 5.3 | 1.7 |
| 18. |  | 188 | 453 | 138 | 115 | 118 | 3.9 | 16.4 | 4.7 | 1.7 |
|  |  | 172 | 413 | 149 | 116 | 124 | 3.8 | 16.0 | 5.4 | 1.7 |
| 1. | High-50 | 40 | 153 | 367 | 329 | 332 | 6.0 | 16.2 | 7.9 | 1.9 |
| 7. |  | 48 | 157 | 377 | 330 | 333 | 6.1 | 7.9 | 5.5 | 1.7 |
| 15. |  | 40 | 131 | 369 | 339 | 342 | 6.3 | 6.0 | 4.1 | 1.6 |
|  |  | 43 | 147 | 371 | 333 | 336 | 6.1 | 10.0 | 5.8 | 1.7 |
| 5. | High-100 | 26 | 2345 | 352 | 301 | 303 | 8.0 | 6.5 | 5.4 | 1.7 |
| 13. |  | 32 | 2682 | 330 | 290 | 303 | 8.1 | 5.3 | 3.8 | 1.6 |
| 20. |  | 27 | 2020 | 347 | 310 | 313 | 8.0 | 7.5 | 5.4 | 1.7 |
|  |  | 28 | 2349 | 343 | 300 | 306 | 8.0 | 6.4 | 4.9 | 1.7 |
| 4. | Idle | 96 | 148 | 166 | 123 | 128 | 2.8 | 7.9 | 4.2 | 1.6 |
| 11. |  | 94 | 131 | 162 | 129 | 130 | 3.0 | 7.8 | 4.2 | 1.6 |
| 19. |  | 96 | 131 | 150 | 128 | 133 | 3.0 | 4.5 | 2.5 | 1.4 |
|  |  | 95 | 137 | 159 | 127 | 130 | 2.9 | 6.7 | 3.6 | 1.5 |

## TABLE K-4. EMISSIONS OBTAINED SIMULTANEOUSLY WITH ODOR RATINGS - MERCEDES 240D EVALUATION

| | | | | | NDIR | C. L. | | | DOAS Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Load | Date | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, µg/l | LCO, µg/l | TIA | Air Flow, kg/min |
| 1800 rpm | 2% | 4/20/76 | 65 | 179 | 71 | 64 | 71 | 2.4 | 7.1 | 4.1 | 1.6 | 2.04 |
| | | 4/22/76 | 72 | 167 | 60 | 61 | 64 | 2.3 | 7.4 | 4.0 | 1.6 | 1.82 |
| | | Average | 69 | 173 | 66 | 63 | 68 | 2.4 | 7.3 | 4.1 | 1.6 | 1.93 |
| 1800 rpm<br>33 mph | 50% | 4/20/76 | 51 | 140 | 376 | 333 | 334 | 6.6 | 6.8 | 4.1 | 1.6 | 2.02 |
| | | 4/22/76 | 84 | 157 | 326 | 282 | 283 | 6.7 | 9.3 | 5.3 | 1.7 | 2.02 |
| | | Average | 68 | 149 | 351 | 308 | 309 | 6.7 | 8.1 | 4.7 | 1.7 | 2.02 |
| 1800 rpm<br>33 mph | 100% | 4/20/76 | 47 | 255 | 379 | 362 | 366 | 10.8 | 6.2 | 4.9 | 1.7 | 2.04 |
| | | 4/22/76 | 75 | 317 | 343 | 317 | 322 | 10.7 | 5.8 | 4.6 | 1.7 | 2.06 |
| | | Average | 61 | 286 | 361 | 340 | 344 | 10.8 | 6.0 | 4.8 | 1.7 | 2.05 |
| 3000 rpm | 2% | 4/20/76 | 52 | 356 | 99 | 88 | 93 | 3.2 | 6.3 | 3.7 | 1.6 | 3.33 |
| | | 4/22/76 | 100 | 349 | 72 | 72 | 75 | 3.0 | 8.7 | 4.4 | 1.7 | 3.12 |
| | | Average | 76 | 353 | 86 | 80 | 84 | 3.1 | 7.5 | 4.1 | 1.7 | 3.23 |
| 3000 rpm<br>56 mph | 50% | 4/20/76 | 41 | 179 | 430 | 384 | 390 | 7.4 | 7.4 | 5.2 | 1.7 | 3.29 |
| | | 4/22/76 | 59 | 179 | 371 | 330 | 341 | 7.3 | 6.9 | 4.6 | 1.7 | 3.28 |
| | | Average | 50 | 179 | 401 | 357 | 366 | 7.4 | 7.2 | 4.9 | 1.7 | 3.29 |
| 3000 rpm<br>56 mph | 100% | 4/20/76 | 43 | 407 | 513 | 474 | 475 | 12.3 | 7.0 | 5.8 | 1.7 | 3.28 |
| | | 4/22/76 | 83 | 453 | 441 | 413 | 413 | 12.0 | 4.7 | 4.2 | 1.6 | 3.23 |
| | | Average | 63 | 430 | 477 | 444 | 444 | 12.2 | 5.9 | 5.0 | 1.7 | 3.26 |
| Idle | | 4/20/76 | 88 | 148 | 99 | 85 | 95 | 2.4 | 7.4 | 3.7 | 1.6 | 0.66 |
| | | 4/22/76 | 104 | 153 | 90 | 88 | 90 | 2.4 | 8.3 | 3.7 | 1.6 | 0.69 |
| | | Average | 96 | 151 | 95 | 87 | 93 | 2.4 | 7.9 | 3.7 | 1.6 | 0.68 |

## TABLE K-5. GASEOUS EMISSIONS SUMMARY

Vehicle: Mercedes 240D

Date: April 20, 1976

| | | | | NDIR | C. L. | | | DOAS Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Operating Condition | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, µg/l | LCO, µg/l | TIA | Air Flow, kg/min |
| 7. | Inter-2 | 80 | 184 | 60 | 60 | 70 | 2.4 | 7.4 | 4.1 | 1.6 | 2.03 |
| 11. | | 52 | 184 | 76 | 63 | 70 | 2.3 | 6.9 | 4.2 | 1.6 | 2.07 |
| 16. | | 64 | 170 | 76 | 70 | 72 | 2.4 | 6.9 | 4.1 | 1.6 | 2.02 |
| | | 65 | 179 | 71 | 64 | 71 | 2.4 | 7.1 | 4.1 | 1.6 | 2.04 |
| 4. | Inter-50 | 52 | 144 | 386 | 325 | 320 | 6.7 | 6.6 | 3.9 | 1.6 | 2.04 |
| 14. | | 56 | 144 | 369 | 330 | 335 | 6.3 | 7.4 | 4.4 | 1.7 | 2.04 |
| 20. | | 48 | 131 | 373 | 345 | 348 | 6.7 | 6.3 | 4.1 | 1.6 | 1.99 |
| | | 51 | 140 | 376 | 333 | 334 | 6.6 | 6.8 | 4.1 | 1.6 | 2.02 |
| 3. | Inter-100 | 40 | 237 | 360 | 350 | 355 | 11.0 | 6.2 | 5.2 | 1.7 | 2.06 |
| 13. | | 56 | 264 | 382 | 360 | 362 | 10.5 | 7.7 | 5.2 | 1.7 | 2.03 |
| 21. | | 44 | 264 | 395 | 375 | 380 | 11.0 | 4.7 | 4.3 | 1.6 | 2.03 |
| | | 47 | 255 | 379 | 362 | 366 | 10.8 | 6.2 | 4.9 | 1.7 | 2.04 |
| 5. | High-2 | 52 | 385 | 95 | 85 | 90 | 3.2 | 6.2 | 3.6 | 1.6 | 3.32 |
| 10. | | 40 | 317 | 103 | 90 | 95 | 3.0 | 6.6 | 4.0 | 1.6 | 3.28 |
| 17. | | 64 | 371 | 99 | 88 | 95 | 3.3 | 6.2 | 3.6 | 1.6 | 3.38 |
| | | 52 | 356 | 99 | 88 | 93 | 3.2 | 6.3 | 3.7 | 1.6 | 3.33 |
| 2. | High-50 | 28 | 157 | 434 | 385 | 400 | 7.4 | 8.4 | 6.2 | 1.8 | 3.25 |
| 8. | | 60 | 210 | 434 | 388 | 390 | 7.5 | 9.3 | 5.7 | 1.8 | 3.35 |
| 15. | | 36 | 170 | 421 | 380 | 380 | 7.3 | 4.6 | 3.8 | 1.6 | 3.26 |
| | | 41 | 179 | 430 | 384 | 390 | 7.4 | 7.4 | 5.2 | 1.7 | 3.29 |
| 1. | High-100 | 40 | 425 | 510 | 455 | 455 | 12.5 | 7.9 | 6.8 | 1.8 | 3.29 |
| 9. | | 48 | 385 | 514 | 483 | 485 | 12.1 | 7.2 | 5.5 | 1.7 | 3.27 |
| 19. | | 40 | 412 | 514 | 485 | 485 | 12.3 | 5.8 | 5.2 | 1.7 | 3.28 |
| | | 43 | 407 | 513 | 474 | 475 | 12.3 | 7.0 | 5.8 | 1.7 | 3.28 |
| 6. | Idle | 88 | 144 | 95 | 85 | 95 | 2.4 | 7.5 | 3.8 | 1.6 | 0.67 |
| 12. | | 88 | 157 | 99 | 80 | 90 | 2.3 | 7.3 | 3.9 | 1.6 | 0.66 |
| 18. | | 88 | 144 | 103 | 90 | 100 | 2.5 | 7.3 | 3.3 | 1.5 | 0.65 |
| | | 88 | 148 | 99 | 85 | 95 | 2.4 | 7.4 | 3.7 | 1.6 | 0.66 |

## TABLE K-6. GASEOUS EMISSIONS SUMMARY

Vehicle: Mercedes 240 D

Date: April 22, 1976

| | | | | NDIR | C. L. | | | DOAS Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Operating Condition | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$ % | LCA, µg/l | LCO, µg/l | TIA | Air Flow, kg/min |
| 6. | Inter-2 | 104 | 264 | 60 | 58 | 60 | 2.6 | 9.3 | 4.6 | 1.7 | 2.53 |
| 11. | | 52 | 118 | 60 | 60 | 63 | 2.1 | --- | --- | --- | 1.50 |
| 15. | | 60 | 118 | 60 | 65 | 70 | 2.2 | 5.4 | 3.3 | 1.5 | 1.42 |
| | | 72 | 167 | 60 | 61 | 64 | 2.3 | 7.4 | 4.0 | 1.6 | 1.82 |
| 2. | Inter-50 | 64 | 131 | 330 | 280 | 280 | 6.6 | 7.5 | 5.0 | 1.7 | 2.03 |
| 8. | | 80 | 184 | 330 | 285 | 288 | 6.8 | 11.4 | 5.9 | 1.8 | 2.03 |
| 18. | | 108 | 157 | 318 | 280 | 280 | 6.6 | 8.9 | 4.9 | 1.7 | 1.99 |
| | | 84 | 157 | 326 | 282 | 283 | 6.7 | 9.3 | 5.3 | 1.7 | 2.02 |
| 1. | Inter-100 | 64 | 304 | 343 | 330 | 340 | 10.8 | 5.1 | 4.6 | 1.7 | 2.08 |
| 9. | | 80 | 317 | 334 | 305 | 310 | 10.7 | 6.5 | 4.6 | 1.7 | 2.07 |
| 19. | | 80 | 331 | 352 | 315 | 315 | 10.5 | 5.9 | 4.6 | 1.7 | 2.02 |
| | | 75 | 317 | 343 | 317 | 322 | 10.7 | 5.8 | 4.6 | 1.7 | 2.06 |
| 5. | High-2 | 72 | 398 | 91 | [illegible] | 85 | 3.2 | 7.3 | 4.2 | 1.6 | 3.40 |
| 12. | | 128 | 264 | 45 | 55 | 60 | 2.6 | 10.2 | 4.8 | 1.7 | 2.58 |
| 17. | | 100 | 385 | 80 | 78 | 80 | 3.1 | 8.5 | 4.3 | 1.6 | 3.38 |
| | | 100 | 349 | 72 | 72 | 75 | 3.0 | 8.7 | 4.4 | 1.7 | 3.12 |
| 7. | High-50 | 72 | 197 | 364 | 335 | 343 | 7.4 | 6.1 | 4.3 | 1.6 | 3.32 |
| 14. | | 48 | 157 | 390 | 340 | 360 | 7.4 | 8.2 | 4.8 | 1.7 | 3.24 |
| 20. | | 56 | 184 | 360 | 315 | 320 | 7.0 | 6.5 | 4.7 | 1.7 | 3.29 |
| | | 59 | 179 | 371 | 330 | 341 | 7.3 | 6.9 | 4.6 | 1.7 | 3.28 |
| 3. | High-100 | 76 | 453 | 429 | 410 | 410 | 12.1 | 4.3 | 4.1 | 1.6 | 3.25 |
| 13. | | 104 | 480 | 438 | 420 | 420 | 12.1 | 4.6 | 3.9 | 1.6 | 3.29 |
| 21. | | 68 | 425 | 456 | 410 | 410 | 11.8 | 5.1 | 4.6 | 1.7 | 3.16 |
| | | 83 | 453 | 441 | 413 | 413 | 12.0 | 4.7 | 4.2 | 1.6 | 3.23 |
| 4. | Idle | 88 | 170 | 99 | 93 | 95 | 2.5 | 8.6 | 4.1 | 1.6 | 0.69 |
| 10. | | 116 | 131 | 95 | 90 | 95 | 2.4 | 9.2 | 3.8 | 1.6 | 0.70 |
| 16. | | 108 | 157 | 76 | 80 | 80 | 2.4 | 7.1 | 3.2 | 1.5 | 0.68 |
| | | 104 | 153 | 90 | 88 | 90 | 2.4 | 8.3 | 3.7 | 1.6 | 0.69 |

## TABLE K-7. EMISSIONS OBTAINED SIMULTANEOUSLY WITH ODOR RATINGS -- MERCEDES 300D EVALUATION

| | | | | | NDIR | C. L. | | | DOAS Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Load | Date | HC, ppm | CO, ppm | NO, ppm | NO, ppm | NOx, ppm | $CO_2$, % | LCA, µg/l | LCO, µg/l | TIA | Air Flow, kg/min |
| 1740 rpm | 2% | 4/14/76 | 85 | 214 | 68 | 58 | 71 | 2.7 | 8.3 | 4.4 | 1.6 | 3.24 |
| | | 4/16/76 | 72 | 159 | 73 | 69 | 75 | 2.5 | 6.7 | 4.3 | 1.6 | 2.62 |
| | | Average | 79 | 187 | 71 | 64 | 73 | 2.6 | 7.5 | 4.4 | 1.6 | 2.93 |
| 1740 rpm<br>33 mph | 50% | 4/14/76 | 69 | 153 | 178 | 164 | 175 | 4.4 | 10.8 | 5.3 | 1.7 | 2.66 |
| | | 4/16/76 | 66 | 138 | 199 | 170 | 178 | 4.4 | 8.7 | 4.8 | 1.7 | 2.74 |
| | | Average | 68 | 146 | 189 | 167 | 177 | 4.4 | 9.8 | 5.1 | 1.7 | 2.70 |
| 1740 rpm<br>33 mph | 100% | 4/14/76 | 61 | 130 | 262 | 232 | 245 | 5.5 | 8.8 | 4.7 | 1.7 | 2.70 |
| | | 4/16/76 | 58 | 133 | 290 | 253 | 259 | 5.6 | 7.2 | 4.7 | 1.7 | 2.76 |
| | | Average | 60 | 132 | 276 | 243 | 252 | 5.6 | 8.0 | 4.7 | 1.7 | 2.73 |
| 2900 rpm | 2% | 4/14/76 | 67 | 268 | 102 | 82 | 94 | 3.1 | 9.0 | 4.1 | 1.6 | 4.21 |
| | | 4/16/76 | 55 | 202 | 106 | 93 | 101 | 3.1 | 6.9 | 4.3 | 1.7 | 4.18 |
| | | Average | 61 | 235 | 104 | 88 | 98 | 3.1 | 8.0 | 4.2 | 1.7 | 4.20 |
| 2900 rpm<br>56 mph | 50% | 4/14/76 | 42 | 153 | 340 | 302 | 308 | 6.4 | 8.8 | 5.0 | 1.7 | 4.17 |
| | | 4/16/76 | 43 | 164 | 342 | 322 | 331 | 6.3 | 8.8 | 5.3 | 1.7 | 4.24 |
| | | Average | 43 | 159 | 341 | 312 | 320 | 6.4 | 8.8 | 5.2 | 1.7 | 4.21 |
| 2900 rpm<br>56 mph | 100% | 4/14/76 | 48 | 157 | 487 | 437 | 446 | 9.4 | 8.7 | 5.6 | 1.8 | 4.14 |
| | | 4/16/76 | 43 | 138 | 493 | 474 | 482 | 9.4 | 7.5 | 5.3 | 1.7 | 4.24 |
| | | Average | 46 | 148 | 490 | 456 | 464 | 9.4 | 8.1 | 5.5 | 1.8 | 4.19 |
| Idle | | 4/14/76 | 121 | 186 | 109 | 84 | 94 | 2.5 | 12.1 | 4.8 | 1.7 | 0.87 |
| | | 4/16/76 | 117 | 158 | 98 | 86 | 96 | 2.5 | 9.1 | 4.3 | 1.6 | 0.88 |
| | | Average | 119 | 172 | 104 | 85 | 95 | 2.5 | 10.6 | 4.6 | 1.7 | 0.88 |

## TABLE K-8. GASEOUS EMISSIONS SUMMARY

Vehicle: Mercedes 300D

Date: April 14, 1976

| Run No. | Operating Condition | HC, ppm | CO, ppm | NDIR NO, ppm | C. L. NO, ppm | C. L. NOx, ppm | $CO_2$, % | DOAS Results LCA, µg/l | DOAS Results LCO, µg/l | DOAS Results TIA | Air Flow, kg/min |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6. | Inter-2 | 72 | 224 | 76 | 60 | 69 | 2.7 | 8.7 | 4.4 | 1.7 | 3.24 |
| 11. | | 119 | 227 | 55 | 58 | 71 | 2.7 | 7.8 | 4.4 | 1.6 | 3.23 |
| 15. | | 64 | 191 | 72 | 57 | 74 | 2.6 | 8.3 | 4.4 | 1.6 | 3.24 |
| | | 85 | 214 | 68 | 58 | 71 | 2.7 | 8.3 | 4.4 | 1.6 | 3.24 |
| 2. | Inter-50 | 74 | 170 | 186 | 155 | 167 | 4.2 | 13.0 | 6.7 | 1.8 | 2.62 |
| 8. | | 76 | 144 | 146 | 166 | 173 | 4.6 | 10.3 | 4.5 | 1.7 | 2.69 |
| 18. | | 58 | 144 | 202 | 170 | 184 | 4.4 | 9.1 | 4.6 | 1.7 | 2.66 |
| | | 69 | 153 | 178 | 164 | 175 | 4.4 | 10.8 | 5.3 | 1.7 | 2.66 |
| 1. | Inter-100 | 56 | 131 | 284 | 237 | 247 | 5.6 | 10.0 | 5.7 | 1.8 | 2.67 |
| 9. | | 65 | 131 | 218 | 220 | 234 | 5.5 | 8.2 | 4.0 | 1.6 | 2.68 |
| 19. | | 62 | 127 | 284 | 238 | 253 | 5.4 | 8.3 | 4.4 | 1.6 | 2.76 |
| | | 61 | 130 | 262 | 232 | 245 | 5.5 | 8.8 | 4.7 | 1.7 | 2.70 |
| 5. | High-2 | 68 | 277 | 107 | 89 | 94 | 3.2 | 9.5 | 4.5 | 1.7 | 4.29 |
| 12. | | 66 | 264 | 97 | 78 | 97 | 3.1 | 9.5 | 4.0 | 1.6 | 4.18 |
| 17. | | 66 | 264 | 103 | 80 | 92 | 3.0 | 8.0 | 3.8 | 1.6 | 4.16 |
| | | 67 | 268 | 102 | 82 | 94 | 3.1 | 9.0 | 4.1 | 1.6 | 4.21 |
| 7. | High-50 | 46 | 170 | 319 | 297 | 303 | 6.4 | 7.3 | 4.3 | 1.6 | 4.15 |
| 14. | | 35 | 138 | 367 | 312 | 315 | 6.4 | 9.4 | 4.9 | 1.7 | 4.09 |
| 20. | | 44 | 150 | 334 | 296 | 307 | 6.3 | 9.6 | 5.9 | 1.8 | 4.28 |
| | | 42 | 153 | 340 | 302 | 308 | 6.4 | 8.8 | 5.0 | 1.7 | 4.17 |
| 3. | High-100 | 52 | 184 | 483 | 435 | 441 | 9.6 | 9.2 | 5.8 | 1.8 | 4.20 |
| 13. | | 44 | 144 | 514 | 432 | 440 | 9.2 | 8.1 | 5.1 | 1.7 | 4.21 |
| 21. | | 48 | 144 | 465 | 444 | 456 | 9.4 | 8.7 | 5.9 | 1.8 | 4.01 |
| | | 48 | 157 | 487 | 437 | 446 | 9.4 | 8.7 | 5.6 | 1.8 | 4.14 |
| 4. | Idle | 96 | 210 | 122 | 98 | 101 | 2.6 | 11.8 | 5.2 | 1.7 | 0.84 |
| 10. | | 136 | 165 | 107 | 76 | 88 | 2.5 | 13.3 | 4.8 | 1.7 | 0.89 |
| 16. | | 130 | 184 | 99 | 78 | 93 | 2.4 | 11.3 | 4.3 | 1.6 | 0.89 |
| | | 121 | 186 | 109 | 84 | 94 | 2.5 | 12.1 | 4.8 | 1.7 | 0.87 |

## TABLE K-9. GASEOUS EMISSIONS SUMMARY

Vehicle: Mercedes 300D

Date: April 16, 1976

| Run No. | Operating Condition | HC, ppm | CO, ppm | NDIR NO, ppm | C. L. NO, ppm | C. L. NO$_x$, ppm | CO$_2$ % | DOAS Results LCA, μg/l | DOAS Results LCO, μg/l | DOAS Results TIA | Air Flow, kg/min |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7. | Inter-2 | 60 | 157 | 84 | 70 | 78 | 2.5 | 5.6 | 3.8 | 1.6 | 2.66 |
| 11. | | 89 | 157 | 60 | 69 | 74 | 2.5 | 6.6 | 4.2 | 1.6 | 2.61 |
| 16. | | 66 | 164 | 76 | 67 | 73 | 2.5 | 7.8 | 4.8 | 1.7 | 2.58 |
| | | 72 | 159 | 73 | 69 | 75 | 2.5 | 6.7 | 4.3 | 1.6 | 2.62 |
| 4. | Inter-50 | 62 | 157 | 202 | 176 | 179 | 4.4 | 8.0 | 4.9 | 1.7 | 2.76 |
| 14. | | 78 | 133 | 202 | 173 | 183 | 4.4 | 9.6 | 4.8 | 1.7 | 2.73 |
| 20. | | 58 | 125 | 194 | 162 | 172 | 4.3 | 8.5 | 4.8 | 1.7 | 2.73 |
| | | 66 | 138 | 199 | 170 | 178 | 4.4 | 8.7 | 4.8 | 1.7 | 2.74 |
| 3. | Inter-100 | 54 | 144 | 297 | 265 | 270 | 5.7 | 7.2 | 4.7 | 1.7 | 2.73 |
| 13. | | 70 | 123 | 305 | 264 | 272 | 5.7 | 7.6 | 4.5 | 1.7 | 2.79 |
| 21. | | 50 | 131 | 267 | 230 | 236 | 5.2 | 6.9 | 5.0 | 1.7 | 2.75 |
| | | 58 | 133 | 290 | 253 | 259 | 5.6 | 7.2 | 4.7 | 1.7 | 2.76 |
| 5. | High-2 | 54 | 237 | 115 | 95 | 103 | 3.1 | 6.6 | 4.0 | 1.6 | 4.17 |
| 10. | | 56 | 118 | 101 | 93 | 101 | 3.1 | 7.2 | 4.4 | 1.7 | 4.12 |
| 17. | | 56 | 250 | 101 | 90 | 100 | 3.1 | 7.0 | 4.4 | 1.7 | 4.26 |
| | | 55 | 202 | 106 | 93 | 101 | 3.1 | 6.9 | 4.3 | 1.7 | 4.18 |
| 2. | High-50 | 38 | 164 | 339 | 310 | 316 | 6.2 | 9.6 | 6.0 | 1.8 | 4.19 |
| 8. | | 44 | 157 | 343 | 335 | 348 | 6.6 | 9.6 | 5.3 | 1.7 | 4.29 |
| 15. | | 48 | 170 | 345 | 320 | 329 | 6.2 | 7.1 | 4.6 | 1.7 | 4.25 |
| | | 43 | 164 | 342 | 322 | 331 | 6.3 | 8.8 | 5.3 | 1.7 | 4.24 |
| 1. | High-100 | 44 | 144 | 485 | 493 | 498 | 9.1 | 9.1 | 6.1 | 1.8 | 4.22 |
| 9. | | 44 | 138 | 478 | 470 | 480 | 9.4 | 6.3 | 4.4 | 1.7 | 4.20 |
| 19. | | 40 | 131 | 515 | 460 | 468 | 9.6 | 7.2 | 5.3 | 1.7 | 4.30 |
| | | 43 | 138 | 493 | 474 | 482 | 9.4 | 7.5 | 5.3 | 1.7 | 4.24 |
| 6. | Idle | 102 | 157 | 111 | 93 | 102 | 2.5 | 8.7 | 4.2 | 1.6 | 0.91 |
| 12. | | 130 | 161 | 84 | 81 | 94 | 2.5 | 9.2 | 4.1 | 1.6 | 0.87 |
| 18. | | 118 | 157 | 99 | 83 | 92 | 2.5 | 9.5 | 4.6 | 1.7 | 0.86 |
| | | 117 | 158 | 98 | 86 | 96 | 2.5 | 9.1 | 4.3 | 1.6 | 0.88 |

## TABLE K-10. EMISSIONS OBTAINED SIMULTANEOUSLY WITH ODOR RATINGS -- PEUGEOT 204D EVALUATION

| | | | | | NDIR | C. L. | | | DOAS Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operating Condition | Load | Date | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, µg/l | LCO, µg/l | TIA | Air Flow, kg/min |
| 2100 rpm | 2% | 3/31/76 | 345 | 398 | 38 | 35 | 57 | 2.1 | 23.1 | 11.3 | 2.1 | 1.29 |
| | | 4/02/76 | 239 | 353 | 33 | 28 | 45 | 2.0 | 20.4 | 9.8 | 2.0 | 1.27 |
| | | Average | 292 | 376 | 36 | 32 | 51 | 2.1 | 21.8 | 10.6 | 2.1 | 1.28 |
| 2100 rpm<br>33 mph | 50% | 3/31/76 | 592 | 367 | 149 | 120 | 162 | 4.6 | 51.5 | 18.1 | 2.2 | 1.25 |
| | | 4/02/76 | 808 | 349 | 130 | 112 | 143 | 4.8 | 42.1 | 15.0 | 2.2 | 1.26 |
| | | Average | 700 | 358 | 140 | 116 | 153 | 4.7 | 46.8 | 16.6 | 2.2 | 1.26 |
| 2100 rpm<br>33 mph | 100% | 3/31/76 | 853 | 335 | 233 | 215 | 222 | 8.7 | 99.0 | 32.8 | 2.5 | 1.23 |
| | | 4/02/76 | 832 | 367 | 203 | 192 | 193 | 8.5 | 82.0 | 26.6 | 2.4 | 1.23 |
| | | Average | 843 | 351 | 218 | 204 | 208 | 8.6 | 90.5 | 29.7 | 2.5 | 1.23 |
| 3500 rpm | 2% | 3/31/76 | 351 | 590 | 64 | 50 | 70 | 2.8 | 26.6 | 13.7 | 2.1 | 1.98 |
| | | 4/02/76 | 288 | 530 | 45 | 40 | 52 | 3.0 | 24.1 | 12.2 | 2.1 | 2.07 |
| | | Average | 320 | 560 | 55 | 45 | 61 | 2.9 | 25.4 | 13.0 | 2.1 | 2.03 |
| 3500 rpm<br>56 mph | 50% | 3/31/76 | 408 | 335 | 226 | 198 | 215 | 6.0 | 46.6 | 18.5 | 2.3 | 2.07 |
| | | 4/02/76 | 303 | 326 | 185 | 177 | 187 | 6.1 | 34.7 | 15.7 | 2.2 | 2.07 |
| | | Average | 356 | 331 | 206 | 188 | 201 | 6.1 | 40.7 | 17.1 | 2.3 | 2.07 |
| 3500 rpm<br>56 mph | 100% | 3/31/76 | 413 | 344 | 290 | 258 | 260 | 9.0 | 59.0 | 24.6 | 2.3 | 2.04 |
| | | 4/02/76 | 340 | 326 | 243 | 223 | 227 | 9.3 | 67.5 | 27.2 | 2.4 | 2.04 |
| | | Average | 377 | 335 | 267 | 241 | 244 | 9.2 | 63.3 | 25.9 | 2.4 | 2.04 |
| Idle | | 3/31/76 | 569 | 549 | 35 | 26 | 55 | 2.2 | 29.0 | 13.1 | 2.1 | 0.83 |
| | | 4/02/76 | 508 | 485 | 29 | 20 | 45 | 2.1 | 22.4 | 11.6 | 2.1 | 0.85 |
| | | Average | 539 | 517 | 32 | 23 | 50 | 2.2 | 25.7 | 12.4 | 2.1 | 0.84 |

## TABLE K-11. GASEOUS EMISSIONS SUMMARY

Vehicle: Peugeot 204D

Date: March 31, 1976

| | | | | NDIR | C. L. | | | DOAS Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Operating Condition | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, µg/l | LCO, µg/l | TIA | Air Flow, kg/min |
| 5. | Inter-2 | 384 | 425 | 45 | 35 | 55 | 2.1 | 20.9 | 10.1 | 2.0 | 1.28 |
| 11. | | 328 | 358 | 38 | 40 | 60 | 2.1 | 23.2 | 11.4 | 2.1 | 1.30 |
| 14. | | 328 | 412 | 30 | 30 | 55 | 2.1 | 25.3 | 12.4 | 2.1 | 1.30 |
| | | 345 | 398 | 38 | 35 | 57 | 2.1 | 23.1 | 11.3 | 2.1 | 1.29 |
| 4. | Inter-50 | 592 | 398 | 162 | 135 | 160 | 4.8 | 38.8 | 13.0 | 2.1 | 1.25 |
| 10. | | 616 | 317 | 154 | 110 | 165 | 4.6 | 60.5 | 21.5 | 2.3 | 1.25 |
| 17. | | 568 | 385 | 130 | 115 | 160 | 4.5 | 55.1 | 19.7 | 2.3 | 1.25 |
| | | 592 | 367 | 149 | 120 | 162 | 4.6 | 51.5 | 18.1 | 2.2 | 1.25 |
| 8. | Inter-100 | 976 | 344 | 226 | 205 | 210 | 8.9 | 123.7 | 40.6 | 2.6 | 1.24 |
| 15. | | 840 | 331 | 230 | 210 | 220 | 8.4 | 84.3 | 28.6 | 2.5 | 1.22 |
| 21. | | 744 | 331 | 243 | 230 | 235 | 8.8 | 89.1 | 29.1 | 2.5 | 1.22 |
| | | 853 | 335 | 233 | 215 | 222 | 8.7 | 99.0 | 32.8 | 2.5 | 1.23 |
| 3. | High-2 | 324 | 618 | 72 | 50 | 65 | 2.9 | 27.9 | 12.9 | 2.1 | 2.10 |
| 6. | | 496 | 618 | 41 | 35 | 60 | 2.5 | 26.8 | 14.4 | 2.2 | 1.72 |
| 18. | | 232 | 535 | 80 | 65 | 85 | 3.0 | 25.2 | 13.7 | 2.1 | 2.11 |
| | | 351 | 590 | 64 | 50 | 70 | 2.8 | 26.6 | 13.7 | 2.1 | 1.98 |
| 2. | High-50 | 352 | 371 | 243 | --- | --- | 5.9 | 37.6 | 15.4 | 2.2 | 2.10 |
| 12. | | 408 | 304 | 214 | 195 | 215 | 5.9 | 44.1 | 17.8 | 2.3 | 2.06 |
| 19. | | 464 | 331 | 222 | 200 | 215 | 6.3 | 58.1 | 22.3 | 2.4 | 2.04 |
| | | 408 | 335 | 226 | 198 | 215 | 6.0 | 46.6 | 18.5 | 2.3 | 2.07 |
| 1. | High-100 | 392 | 412 | 313 | --- | --- | 9.2 | 17.1 | 10.4 | 2.0 | 2.07 |
| 9. | | 512 | 317 | 272 | 245 | 250 | 8.8 | 87.2 | 34.1 | 2.5 | 2.04 |
| 16. | | 336 | 304 | 284 | 270 | 270 | 8.9 | 72.6 | 29.2 | 2.5 | 2.02 |
| | | 413 | 344 | 290 | 258 | 260 | 9.0 | 59.0 | 24.6 | 2.3 | 2.04 |
| 7. | Idle | 824 | 645 | 45 | 38 | 55 | 2.1 | 30.0 | 13.4 | 2.1 | 0.78 |
| 13. | | 436 | 494 | 23 | 20 | 50 | 2.2 | 31.6 | 13.1 | 2.1 | 0.85 |
| 20. | | 448 | 507 | 38 | 20 | 60 | 2.2 | 25.5 | 12.7 | 2.1 | 0.85 |
| | | 569 | 549 | 35 | 26 | 55 | 2.2 | 29.0 | 13.1 | 2.1 | 0.83 |

## TABLE K-12. GASEOUS EMISSIONS SUMMARY

Vehicle: Peugeot 204D

Date: April 2, 1976

|  |  |  |  | NDIR | C. L. |  |  | DOAS Results |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Operating Condition | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, μg/l | LCO, μg/l | TIA | Air Flow, kg/min |
| 7. | Inter-2 | 232 | 371 | 23 | 30 | 50 | 1.9 | 20.8 | 11.0 | 2.0 | 1.28 |
| 12. |  | 208 | 317 | 38 | 30 | 45 | 2.0 | 22.6 | 10.2 | 2.0 | 1.24 |
| 18. |  | 276 | 371 | 38 | 25 | 40 | 2.0 | 17.9 | 8.1 | 1.9 | 1.28 |
|  |  | 329 | 353 | 33 | 28 | 45 | 2.0 | 20.4 | 9.8 | 2.0 | 1.27 |
| 5. | Inter-50 | 584 | 331 | 138 | 130 | 160 | 4.7 | 37.5 | 12.9 | 2.1 | 1.25 |
| 10. |  | 896 | 358 | 122 | 100 | 140 | 4.7 | 48.1 | 18.6 | 2.3 | 1.28 |
| 19. |  | 944 | 358 | 130 | 105 | 130 | 4.9 | 40.8 | 13.6 | 2.1 | 1.24 |
|  |  | 808 | 349 | 130 | 112 | 143 | 4.8 | 42.1 | 15.0 | 2.2 | 1.26 |
| 6. | Inter-100 | 816 | 398 | 190 | 205 | 205 | 8.4 | 87.2 | 28.2 | 2.5 | 1.22 |
| 13. |  | 784 | 344 | 202 | 180 | 185 | 8.4 | 72.0 | 24.5 | 2.4 | 1.24 |
| 21. |  | 896 | 358 | 218 | 190 | 190 | 8.6 | 86.8 | 27.1 | 2.4 | 1.24 |
|  |  | 832 | 367 | 203 | 192 | 193 | 8.5 | 82.0 | 26.6 | 2.4 | 1.23 |
| 2. | High-2 | 284 | 562 | 34 | 40 | 50 | 2.9 | 23.4 | 12.5 | 2.1 | 2.02 |
| 9. |  | 292 | 507 | 49 | 40 | 55 | 3.1 | 25.9 | 13.7 | 2.1 | 2.12 |
| 14. |  | 288 | 521 | 53 | 40 | 50 | 3.0 | 22.9 | 10.5 | 2.0 | 2.08 |
|  |  | 288 | 530 | 45 | 40 | 52 | 3.0 | 24.1 | 12.2 | 2.1 | 2.07 |
| 1. | High-50 | 292 | 304 | 194 | 170 | 190 | 6.3 | 43.3 | 18.0 | 2.3 | 2.07 |
| 8. |  | 312 | 344 | 170 | 170 | 190 | 5.9 | 44.8 | 19.8 | 2.3 | 2.08 |
| 17. |  | 304 | 331 | 190 | 190 | 180 | 6.1 | 15.9 | 9.2 | 2.0 | 2.06 |
|  |  | 303 | 326 | 185 | 177 | 187 | 6.1 | 34.7 | 15.7 | 2.2 | 2.07 |
| 4. | High-100 | 300 | 331 | 243 | 230 | 235 | 9.3 | 72.4 | 27.9 | 2.5 | 2.04 |
| 11. |  | 440 | 317 | 235 | 215 | 220 | 9.0 | 66.9 | 27.2 | 2.4 | 2.02 |
| 16. |  | 280 | 331 | 251 | 225 | 225 | 9.5 | 63.2 | 26.5 | 2.4 | 2.06 |
|  |  | 340 | 326 | 243 | 223 | 227 | 9.3 | 67.5 | 27.2 | 2.4 | 2.04 |
| 3. | Idle | 476 | 494 | 19 | 25 | 50 | 2.1 | 21.3 | 11.2 | 2.1 | 0.86 |
| 15. |  | 512 | 480 | 30 | 15 | 40 | 2.1 | 24.0 | 11.7 | 2.1 | 0.85 |
| 20. |  | 536 | 480 | 38 | 20 | 45 | 2.1 | 21.8 | 12.0 | 2.1 | 0.85 |
|  |  | 508 | 485 | 29 | 20 | 45 | 2.1 | 22.4 | 11.6 | 2.1 | 0.85 |

TABLE K-13. EMISSIONS OBTAINED SIMULTANEOUSLY WITH ODOR RATINGS -- PERKINS 6-247 ENGINE, IHC PICKUP EVALUATION

| | | | | | NDIR | C. L. | | | DOAS Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operating Conditions | Load | Date | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, μg/l | LCO, μg/l | TIA | Air Flow, kg/min |
| 1620 rpm | 2% | 4/28/76 | 984 | 938 | 21 | 27 | 40 | 2.0 | 72.9 | 34.4 | 2.5 | 0.81 |
| | | 4/30/76 | 885 | 803 | 33 | 37 | 48 | 2.0 | 50.8 | 24.8 | 2.4 | |
| | | Average | 935 | 871 | 27 | 32 | 44 | 2.0 | 61.9 | 29.6 | 2.5 | 0.81 |
| 1620 rpm<br>33 mph | 50% | 4/28/76 | 260 | 406 | 340 | 298 | 303 | 6.4 | 29.3 | 14.0 | 2.2 | 0.79 |
| | | 4/30/76 | 351 | 407 | 357 | 343 | 348 | 7.2 | 35.4 | 18.6 | 2.2 | |
| | | Average | 306 | 407 | 349 | 321 | 326 | 6.8 | 32.4 | 16.3 | 2.2 | 0.79 |
| 1620 rpm<br>33 mph | 100% | 4/28/76 | 488 | 5309 | 348 | 298 | 308 | 11.6 | 25.6 | 12.0 | 2.0 | 0.78 |
| | | 4/30/76 | 496 | 4879 | 351 | 334 | 343 | 11.0 | 51.3 | 25.7 | 2.4 | |
| | | Average | 492 | 5094 | 350 | 316 | 326 | 11.3 | 38.5 | 18.9 | 2.2 | 0.78 |
| 2700 rpm | 2% | 4/28/76 | 1341 | 918 | 58 | 53 | 64 | 2.6 | 91.1 | 32.3 | 2.5 | 1.33 |
| | | 4/30/76 | 1269 | 819 | 51 | 60 | 77 | 2.6 | 75.6 | 26.7 | 2.4 | |
| | | Average | 1305 | 869 | 55 | 57 | 71 | 2.6 | 83.4 | 29.5 | 2.5 | 1.33 |
| 2700 rpm<br>56 mph | 50% | 4/28/76 | 200 | 344 | 366 | 350 | 355 | 7.7 | 23.9 | 12.6 | 2.0 | 1.33 |
| | | 4/30/76 | 219 | 290 | 399 | 398 | 415 | 7.3 | 41.9 | 22.4 | 2.4 | |
| | | Average | 210 | 317 | 383 | 374 | 385 | 7.5 | 32.9 | 17.5 | 2.2 | 1.33 |
| 2700 rpm<br>56 mph | 100% | 4/28/76 | 587 | 4372 | 359 | 328 | 342 | 12.4 | 52.3 | 28.7 | 2.4 | 1.30 |
| | | 4/30/76 | 476 | 3218 | 433 | 388 | 400 | 11.4 | 37.1 | 22.2 | 2.3 | |
| | | Average | 532 | 3795 | 396 | 358 | 371 | 11.9 | 44.7 | 25.5 | 2.4 | 1.30 |
| Idle | | 4/28/76 | 421 | 572 | 38 | 48 | 68 | 1.6 | 22.7 | 15.4 | 2.2 | 0.31 |
| | | 4/30/76 | 301 | 457 | 68 | 70 | 80 | 1.7 | 18.9 | 15.0 | 2.2 | |
| | | Average | 361 | 515 | 53 | 59 | 74 | 1.7 | 20.8 | 15.2 | 2.2 | 0.31 |

## TABLE K-14 GASEOUS EMISSIONS SUMMARY

Vehicle: IHC Pickup, Perkins 6-247 Engine    Date: Aptil 28, 1976

| | | | | NDIR | C. L. | | | DOAS Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Operating Condition | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, μg/l | LCO, μg/l | TIA | Air Flow, kg/min |
| 7. | Inter-2 | 904 | 928 | 19 | 20 | 40 | 2.2 | 76.4 | 35.4 | 2.6 | 0.81 |
| 11. | | 1088 | 986 | 15 | 25 | 40 | 1.9 | 89.2 | 42.1 | 2.6 | 0.80 |
| 16. | | 960 | 899 | 30 | 35 | 40 | 2.0 | 53.0 | 25.6 | 2.4 | 0.82 |
| | | 984 | 938 | 21 | 27 | 40 | 2.0 | 72.9 | 34.4 | 2.5 | 0.81 |
| 4. | Inter-50 | 196 | 385 | 360 | 300 | 300 | 6.3 | 20.0 | 8.9 | 2.0 | 0.80 |
| 14. | | 272 | 480 | 318 | 300 | 300 | 5.6 | 32.8 | 14.4 | 2.2 | 0.80 |
| 20. | | 312 | 353 | 343 | 295 | 310 | 7.4 | 35.0 | 18.7 | 2.3 | 0.77 |
| | | 260 | 406 | 340 | 298 | 303 | 6.4 | 29.3 | 14.0 | 2.2 | 0.79 |
| 3. | Inter-100 | 400 | 4332 | 386 | 305 | 310 | 11.0 | 15.6 | 7.0 | 1.8 | 0.77 |
| 13. | | 624 | 6717 | 318 | 298 | 315 | 11.8 | 33.1 | 15.6 | 2.2 | 0.79 |
| 21. | | 440 | 4879 | 339 | 290 | 300 | 12.3 | 28.0 | 13.5 | 2.1 | 0.78 |
| | | 488 | 5309 | 348 | 298 | 308 | 11.6 | 25.6 | 12.0 | 2.0 | 0.78 |
| 5. | High-2 | 1312 | 899 | 68 | 55 | 60 | 2.5 | 96.6 | 34.0 | 2.5 | 1.32 |
| 10. | | 1360 | 928 | 53 | 55 | 70 | 2.5 | 107.7 | 38.5 | 2.6 | 1.35 |
| 17. | | 1352 | 928 | 53 | 50 | 62 | 2.7 | 69.1 | 24.5 | 2.4 | 1.33 |
| | | 1341 | 918 | 58 | 53 | 64 | 2.6 | 91.1 | 32.3 | 2.5 | 1.33 |
| 2. | High-50 | 120 | 304 | 364 | 350 | 360 | 7.3 | 13.0 | 4.4 | 1.6 | 1.32 |
| 8. | | 280 | 371 | 352 | 350 | 350 | 7.8 | 32.1 | 22.0 | 2.4 | 1.34 |
| 15. | | 200 | 358 | 382 | 350 | 355 | 8.0 | 26.6 | 11.5 | 2.1 | 1.32 |
| | | 200 | 344 | 366 | 350 | 355 | 7.7 | 23.9 | 12.6 | 2.0 | 1.33 |
| 1. | High-100 | 552 | 4106 | 356 | 335 | 350 | 11.8 | 19.7 | 8.0 | 1.9 | 1.30 |
| 9. | | 554 | 4409 | 352 | 325 | 335 | 12.3 | 72.1 | 39.9 | 2.6 | 1.31 |
| 19. | 656 | 656 | 4602 | 369 | 325 | 340 | 13.2 | 65.0 | 38.1 | 2.6 | 1.30 |
| | | 587 | 4372 | 359 | 328 | 342 | 12.4 | 52.3 | 28.7 | 2.4 | 1.30 |
| 6. | Idle | 408 | 590 | 38 | 45 | 65 | 1.6 | 19.6 | 12.8 | 2.1 | 0.31 |
| 12. | | 392 | 507 | 23 | 50 | 70 | 1.5 | 25.8 | 16.3 | 2.2 | 0.31 |
| 18. | | 464 | 618 | 53 | 50 | 70 | 1.8 | 22.8 | 17.1 | 2.2 | 0.31 |
| | | 421 | 572 | 38 | 48 | 68 | 1.6 | 22.7 | 15.4 | 2.2 | 0.31 |

### TABLE K-15.GASEOUS EMISSIONS SUMMARY

Vehicle: IHC Pickup, Perkins 6-247 Engine

Date: April 30, 1976

| | | | | NDIR | C. L. | | | DOAS Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | Operating Condition | HC, ppm | CO, ppm | NO, ppm | NO, ppm | $NO_x$, ppm | $CO_2$, % | LCA, μg/l | LCO, μg/l | TIA |
| 6. | Inter-2 | 944 | 800 | 38 | 30 | 45 | 2.4 | 43.1 | 25.3 | 2.4 |
| 11. | | 848 | 753 | 27 | 35 | 50 | 1.9 | 48.2 | 20.1 | 2.3 |
| 15. | | 864 | 857 | 34 | 45 | 50 | 1.6 | 61.2 | 29.0 | 2.5 |
| | | 885 | 803 | 33 | 37 | 48 | 2.0 | 50.8 | 24.8 | 2.4 |
| 2. | Inter-50 | 224 | 425 | 386 | 345 | 345 | 6.6 | 26.8 | 13.7 | 2.1 |
| 8. | | 412 | 425 | 322 | 335 | 345 | 9.2 | 39.2 | 21.9 | 2.3 |
| 18. | | 416 | 371 | 364 | 350 | 355 | 5.8 | 40.1 | 20.2 | 2.3 |
| | | 351 | 407 | 357 | 343 | 348 | 7.2 | 35.4 | 18.6 | 2.2 |
| 1. | Inter-100 | 520 | 4879 | 364 | 325 | 335 | 11.0 | 44.0 | 21.6 | 2.3 |
| 9. | | 488 | 5039 | 343 | 338 | 343 | 12.3 | 46.8 | 28.9 | 2.5 |
| 19. | | 480 | 4720 | 347 | 340 | 350 | 9.6 | 63.2 | 26.5 | 2.4 |
| | | 496 | 4879 | 351 | 334 | 343 | 11.0 | 51.3 | 25.7 | 2.4 |
| 5. | High-2 | 1360 | 828 | 64 | 60 | 70 | 3.2 | 89.5 | 32.8 | 2.5 |
| 12. | | 1216 | 786 | 41 | 60 | 80 | 2.5 | 63.3 | 20.7 | 2.3 |
| 17. | | 1232 | 842 | 49 | 60 | 80 | 2.2 | 73.9 | 26.7 | 2.4 |
| | | 1269 | 819 | 51 | 60 | 77 | 2.6 | 75.6 | 26.7 | 2.4 |
| 7. | High-50 | 320 | 317 | 382 | 400 | 415 | 9.7 | 47.6 | 29.3 | 2.5 |
| 14. | | 176 | 277 | 412 | 395 | 405 | 6.1 | 53.3 | 23.5 | 2.4 |
| 20. | | 160 | 277 | 403 | 400 | 410 | 6.1 | 24.9 | 14.4 | 2.2 |
| | | 219 | 290 | 399 | 398 | 415 | 7.3 | 41.9 | 22.4 | 2.4 |
| 3. | High-100 | 452 | 2854 | 416 | 375 | 385 | 14.4 | 23.0 | 15.7 | 2.2 |
| 13. | | 544 | 3418 | 399 | 395 | 415 | 10.3 | 50.8 | 27.1 | 2.4 |
| 21. | | 432 | 3382 | 483 | 395 | 400 | 9.6 | 37.6 | 23.8 | 2.4 |
| | | 476 | 3218 | 433 | 388 | 400 | 11.4 | 37.1 | 22.2 | 2.3 |
| 4. | Idle | 280 | 480 | 87 | 70 | 80 | 2.0 | 20.7 | 15.3 | 2.2 |
| 10. | | 304 | 507 | 57 | 60 | 70 | 1.7 | 18.4 | 18.6 | 2.3 |
| 16. | | 320 | 385 | 60 | 80 | 90 | 1.4 | 17.6 | 11.1 | 2.1 |
| | | 301 | 457 | 68 | 70 | 80 | 1.7 | 18.9 | 15.0 | 2.2 |

# APPENDIX L

# NOISE DATA
FOR
FIVE LD DIESEL VEHICLES

## TABLE L-1. MERCEDES 220 COMPREX DIESEL CAR NOISE DATA - dBA SCALE

Date: July 8, 1975 Wind: 4.8 km/hr SSE

### Acceleration Test (Second Gear)

Ambient: Before Test 42-45 After Test 42-45

| | Pass | | | Arithmetic Average(2) |
|---|---|---|---|---|
| | First | Second | Third | |
| Exterior at 15.24m(1) | | | | |
| Right to Left | 71.5 | 71 | 71.5 | 71.5 |
| Left to Right | 70 | 71.5 | 71.5 | 71.5 |
| Interior | 77.5 | 76 | 78 | 77.8 |
| Fresh Air Blr On | 82 | 83 | 81.5 | 82.5 |

### Constant Speed 48.3 km/hr Driveby

Ambient: Before Test 42-45 After Test 42-45

| | Pass | | | Arithmetic Average(2) |
|---|---|---|---|---|
| | First | Second | Third | |
| Exterior at 15.24m | | | | |
| Right to Left | 59 | 59 | 58.5 | 59 |
| Left to Right | 59 | 58.5 | 59 | 59 |
| Interior | 73.5 (80)(3) | 72 (79)(3) | 74 (80)(3) | 73.8 (80)(3) |
| Fresh Air Blr On | 77.5 (82)(3) | 77 (80)(3) | 78.5 (81)(3) | 78 (81.5)(3) |

### Engine Idle, Vehicle at Rest

Ambient: Before Test 42-45 After Test 42-45

| | Test 1 - Direction A | | | | Test 2 - Direction B | | | | Max. Reading |
|---|---|---|---|---|---|---|---|---|---|
| Interior | 55 (75.5 Blr On) | | | | 54.5 (75 Blr On) | | | | 75.5 |
| | Front | Rear | Left | Right | Front | Rear | Left | Right | |
| Exterior | 66.5 | 59 | 65.5 | 64.5 | 67.5 | 59.5 | 65.5 | 65.5 | 67.5 |

---

(1) According to SAE J-986a

(2) Average of the two highest readings that are within 2 dB of each other

(3) Value obtained at very slight accel from 48.3 km/hr

# TABLE L-2. MERCEDES 240 DIESEL CAR
# NOISE DATA - dBA SCALE

Date: July 8, 1975 Wind: 6.4 km/hr SSE

## Acceleration Test (Second Gear)

Ambient: Before Test 47-48 After Test 47-48

| | Pass | | | Arithmetic |
|---|---|---|---|---|
| | First | Second | Third | Average(2) |
| Exterior at 15.24m(1) | | | | |
| Right to Left | 70 | 70.5 | 70.5 | 70.5 |
| Left to Right | 70 | 70 | 71 | 70.5 |
| Interior | 75 | 74.5 | 75 | 75 |
| Fresh Air Blr On | 78 | 77.5 | 79 | 78.5 |

## Constant Speed 48.3 km/hr Driveby

Ambient: Before Test 47-48 After Test 47-48

| | Pass | | | Arithmetic |
|---|---|---|---|---|
| | First | Second | Third | Average(2) |
| Exterior at 15.24m | | | | |
| Right to Left | 58.5 | 59.5 | 60 | 59.8 |
| Left to Right | 60 | 59.5 | 59.5 | 59.8 |
| Interior | 80 (72)(3) | 80 (72)(3) | 81.5 (71.5)(3) | 80.8 (72)(3) |
| Fresh Air Blr On | 81 (75)(3) | 80 (74.5)(3) | 81 (76)(3) | 81 (75.5)(3) |

## Engine Idle, Vehicle at Rest

Ambient: Before Test 43-45 After Test 43-45

| | Test 1 - Direction A | | | | Test 2 - Direction B | | | | Max. Reading |
|---|---|---|---|---|---|---|---|---|---|
| Interior | 53.5 (70.5 Blr On) | | | | 53.5 (68.5 Blr On) | | | | 70.5 |
| | Front | Rear | Left | Right | Front | Rear | Left | Right | |
| Exterior | 65 | 59.5 | 64.5 | 64.5 | 65.5 | 60 | 65 | 64.5 | 65.5 |

---

(1) According to SAE J-986a

(2) Average of the two highest readings that are within 2 dB of each other

(3) Value obtained at decel from 51.5 to 48.3 km/hr

# TABLE L-3. PEUGEOT 204 DIESEL STATION WAGON NOISE DATA - dBA SCALE

Date: July 9, 1975 Wind: 6.4 km/hr SSE

## Acceleration Test (Second Gear)

Ambient: Before Test 41-45 After Test 41-45

| | Pass | | | Arithmetic |
|---|---|---|---|---|
| | First | Second | Third | Average[2] |
| Exterior at 15.24m[1] | | | | |
| Right to Left | 72 | 71.5 | 72 | 72 |
| Left to Right | 72 | 73 | 71 | 72.5 |
| Interior | 79.5 | 79 | 80 | 79.8 |
| Fresh Air Blr On | 79.5 | 80 | 80 | 80 |

## Constant Speed 48.3 km/hr Driveby

Ambient: Before Test 41-45 After Test 41-45

| | Pass | | | Arithmetic |
|---|---|---|---|---|
| | First | Second | Third | Average[2] |
| Exterior at 15.24m | | | | |
| Right to Left | 63 | 63 | 62.5 | 63 |
| Left to Right | 62 | 63 | 63 | 63 |
| Interior | 69 | 68.5 | 70 | 69.5 |
| Fresh Air Blr On | 72 | 71 | 71.5 | 71.8 |

## Engine Idle, Vehicle at Rest

Ambient: Before Test 41-45 After Test 41-45

| | Test 1 - Direction A | | | | Test 2 - Direction B | | | | Max. Reading |
|---|---|---|---|---|---|---|---|---|---|
| Interior | 57.5 (67.5 Blr On) | | | | 58.5 (66.5 Blr On) | | | | 67.5 |
| | Front | Rear | Left | Right | Front | Rear | Left | Right | |
| Exterior | 69.5 | 59 | 64.5 | 65 | 69 | 59 | 64.5 | 69.5 | 69.5 |

---

(1) According to SAE J-986a

(2) Average of the two highest readings that are within 2 dB of each other

## TABLE L-4. MERCEDES 300D DIESEL CAR
## NOISE DATA - dBA SCALE

Date: July 28, 1975 Wind: 6.0 km/hr SSE

### Acceleration Test (Second Gear)

Ambient: Before Test 42-44 After Test 42-44

| | Pass | | | Arithmetic Average(2) |
|---|---|---|---|---|
| | First | Second | Third | |
| Exterior at 15.24m(1) | | | | |
| Right to Left | 70 | 71.5 | 71.5 | 71.5 |
| Left to Right | 71.5 | 71.5 | 72 | 71.8 |
| Interior | 76 | 75 | 77 | 76.5 |
| Fresh Air Blr On | 79 | 78.5 | 79 | 79 |

### Constant Speed 48.3 km/hr Driveby

Ambient: Before Test 42-44 After Test 42-44

| | Pass | | | Arithmetic Average(2) |
|---|---|---|---|---|
| | First | Second | Third | |
| Exterior to 15.24m | | | | |
| Right to Left | 59.5 | 59.5 | 59.5 | 59.5 |
| Left to Right | 59 | 58.5 | 58.5 | 58.8 |
| Interior | 64 | 63.5 | 63.5 | 63.8 |
| Fresh Air Blr On | 75.5 | 76 | 75 | 75.8 |

### Engine Idle, Vehicle at Rest

Ambient: Before Test 42-44 After Test 42-44

| | Test 1 - Direction A | | | | Test 2 - Direction B | | | | Max. Reading |
|---|---|---|---|---|---|---|---|---|---|
| Interior | 54 (68.5 Blr On) | | | | 54.5 (68.5 Blr On) | | | | 68.5 |
| | Front | Rear | Left | Right | Front | Rear | Left | Right | |
| Exterior | 67 | 58 | 66.5 | 64.5 | 66.5 | 59 | 66.5 | 64.5 | 67 |

---

(1) According to SAE J-986a

(2) Average of the two highest readings that are within 2 dB of each other

# TABLE L-5. PERKINS 6-247 DIESEL LIGHT TRUCK NOISE DATA - dBA SCALE

Date: February 2, 1976 Wind: 12.9 km/hr SW

### Acceleration Test (Third Gear)

Ambient: Before Test 43-48 After Test 43-48

| | Pass | | | Arithmetic Average(2) |
|---|---|---|---|---|
| | First | Second | Third | |
| Exterior at 15.24m(1) | | | | |
| Right to Left | 74 | 74.5 | 74.5 | 74.5 |
| Left to Right | 78.5 | 78.5 | 79.5 | 79 |
| Interior | 80 | 79 | 80.5 | 80.3 |
| Fresh Air Blr On | 79 | 81 | 80 | 80.5 |

### Constant Speed 48.3 km/hr Driveby

Ambient: Before Test 43-47 After Test 43-47

| | Pass | | | Arithmetic Average(2) |
|---|---|---|---|---|
| | First | Second | Third | |
| Exterior at 7.62m | | | | |
| Right to Left | 63 | 63 | 64 | 63.5 |
| Left to Right | 65 | 64 | 65 | 65 |
| Interior | 70 | 71 | 69 | 70.5 |
| Fresh Air Blr On | 72 | 72.5 | 72 | 72.3 |

### Engine Idle, Vehicle at Rest

Ambient: Before Test 43-50 After Test 43-48

| | Test 1 - Direction A | | | | Test 2 - Direction B | | | | Max. Reading |
|---|---|---|---|---|---|---|---|---|---|
| Interior | 63.5 (66 Blr On) | | | | 63.5 (66 Blr On) | | | | 66 |
| | Front | Rear | Left | Right | Front | Rear | Left | Right | |
| Exterior | 72.5 | 65.5 | 68.5 | 67.5 | 72.5 | 65 | 69.5 | 69 | 72.5 |

---

(1) According to SAE J-986a

(2) Average of the two highest readings that are within 2 dB of each other

Inspected by 15